ESTIMATION OF EXPOSURE OF PERSONS IN CALIFORNIA TO PESTICIDE PRODUCTS THAT CONTAIN METHIDATHION

HS-1805

By

Sheryl Beauvais, Staff Toxicologist (Specialist)

August 4, 2005

DRAFT

California Environmental Protection Agency
Department of Pesticide Regulation
Worker Health and Safety Branch
1001 I Street
P.O. Box 4015
Sacramento, California 95812-4015
www.cdpr.ca.gov

ESTIMATION OF EXPOSURE OF PERSONS IN CALIFORNIA TO PESTICIDE PRODUCTS THAT CONTAIN METHIDATHION

ABSTRACT

Methidathion (S-2,3-dihydro-5-methoxy-2-oxo-1,3,4-thiadiazol-3-ylmethyl O,O-dimethylphosphorodithioate) is an organophosphate insecticide/miticide registered for control of agricultural pests. All methidathion products registered in California are restricted use pesticides. Formulations include a wettable powder containing 25% active ingredient (AI) and an emulsifiable concentrate containing 24.4% AI. Methidathion is used on various crops, including citrus, stone and pome fruits, kiwifruit (24c label), nuts, artichokes, olives, safflower, sunflower, alfalfa (grown for seed only), cotton, and ornamental plants (nursery stock only). Almonds, citrus, artichokes, and stone fruits are the predominant crops receiving methidathion applications in California.

Significant exposure scenarios were identified based on uses listed on product labels. A total of ten handler and three reentry scenarios were identified. As adequate exposure data were lacking, handler exposures were estimated using surrogate data from the Pesticide Handler Exposure Database (PHED), and reentry exposures were estimated using dislodgeable foliar residue data for methidathion and transfer factors from surrogate chemicals. Exposure estimates were compared to estimates made by U.S. EPA.

Acute exposure estimates for pesticide handlers varied widely, with airblast applicators having the highest exposure estimates. Acute absorbed daily dosage (acute ADD) estimates for mixer/loaders (M/L) were 0.132, 0.158 and 1.15 mg/kg/day (handling products in support of airblast, groundboom and aerial applications, respectively); mixer/loader/applicator (M/L/A) acute ADD estimates were 0.0034 and 0.190 mg/kg/day (using low-pressure handwands and backpack sprayers, respectively); applicator acute ADD estimates were 0.176, 4.65 and 5.85 mg/kg/day (groundboom, aerial and airblast applications); and the acute ADD estimate for flaggers was 1.90 mg/kg/day.

Fieldworker exposure estimates were generally in the range of the lowest handler estimates. Estimated acute ADD was 0.119 mg/kg/day for cotton/safflower scouts, 0.0026 mg/kg/day for workers harvesting/thinning citrus, and 0.018 mg/kg/day for workers thinning artichokes.

Ambient air exposures and bystander exposures during applications also were estimated. Acute ADD for ambient air exposures in Tulare County were 0.389 µg/kg/day for infants and 0.185 µg/kg/day for adults. Seasonal ADD were 0.047 and 0.022 µg/kg/day for infants and adults, respectively. Annual ADD were 0.035 µg/kg/day for infants and 0.017 µg/kg/day for adults.

Bystander exposure estimates were based on air monitoring done 15 – 150 m from the edge of a Tulare County orange grove during an application. Acute ADD for bystanders was 0.519 µg/kg/day for infants and 0.246 µg/kg/day for adults. Seasonal and annual exposures for bystanders were not estimated, because airborne concentrations are anticipated to reach ambient levels within a few days after each application.

INTRODUCTION

Methidathion (S-2,3-dihydro-5-methoxy-2-oxo-1,3,4-thiadiazol-3-ylmethyl O,O-dimethylphosphorodithioate) is an organophosphate (OP) insecticide/miticide registered for control of agricultural pests. Like other OPs, it is a cholinesterase inhibitor. Methidathion is used on various crops, including citrus, stone and pome fruits, kiwifruit (24c label), nuts, artichokes, olives, safflower, sunflower, alfalfa (grown for seed only), cotton, and ornamental plants (nursery stock only). Almonds, citrus, artichokes, and stone fruits are the predominant crops receiving methidathion applications in California.

Introduced as an insecticide by Geigy, methidathion was first registered with the U.S. Environmental Protection Agency (U.S. EPA) in 1972, and in California in 1977. As of April 2004, four products were registered in California, all by Gowan Company. Methidathion was listed as one of 200 priority chemicals to be reviewed under the Birth Defect Prevention Act of 1984 (California Food and Agriculture Code, Sections 13121-13135), based on possible adverse effects identified in chronic toxicity, oncogenicity and chromosomal aberrations studies. This Exposure Assessment Document (EAD) is the first prepared by the California Department of Pesticide Regulation (DPR) for methidathion, although DPR has conducted studies in which worker exposure was monitored (Maddy *et al*., 1983; Wang *et al*., 1987). A dietary and drinking water risk assessment has been done by DPR (Lewis, 2001), as required by the Food Safety Act of 1989 (Title 3 California Code of Regulations, Sections 13134-13135).

As part of its pesticide Reregistration Eligibility Decision process, U.S. EPA published a Health Evaluation Document for methidathion in 1999 (Travaglini, 1999), and approved an Interim Reregistration Eligibility Document (IRED) in September 2001 (U.S. EPA, 2001). In the IRED, U.S. EPA estimated occupational risk for several scenarios; exposure estimates used in the risk assessment were given in Travaglini (1999), not in U.S. EPA (2001). Information and conclusions presented by Travaglini (1999) and U.S. EPA (2001) were considered by DPR during the preparation of this EAD. However, exposure scenarios considered by DPR differed somewhat from those considered by U.S. EPA. Additionally, several assumptions used in exposure assessments differed between DPR and U.S. EPA. Such differences are discussed in this EAD when appropriate.

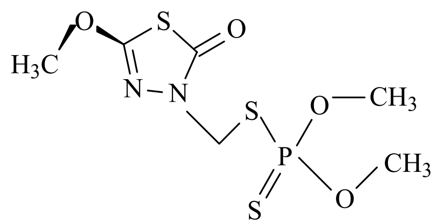
Exposure to methidathion products occurs from pesticide handler and reentry activities; bystanders and others may be exposed to airborne concentrations of methidathion. Pesticide handlers include mixer/loaders (M/L), mixer/loader/applicators (M/L/A), applicators, and flaggers. Reentry activities include any cultivation, harvest or other activity occurring in or near the application site, post-application.

FACTORS DEFINING EXPOSURE SCENARIOS

Physical and Chemical Properties

Methidathion has a moderate water solubility and a low vapor pressure. Technical methidathion is fairly stable in storage, with 2% decomposition in 12 months at 20 - 25°C, and 10% decomposition in 12 months at 35°C (Lail, 1991). Physical and chemical properties for methidathion are listed below (Newell, 1987; Rordorf, 1988; Lail, 1991; Tomlin, 1994).

- Chemical Name: S-2,3-dihydro-5-methoxy-2-oxo-1,3,4-thiadiazol-3-ylmethyl O,O-dimethylphosphorodithioate
- Trade Names: Supracide® (all California registrations), Suprathion®, Medacide®, Ultracide®
- CAS Registry No.: 950-37-8
- Structural Formula:



- Empirical Formula: $C_6H_{11}N_2O_4PS_3$
- Molecular weight: 302.3 g
- Density: 1.445 g/ml
- Solubility: Water (22°C) : 220 mg/L
  Solvents (all at 20°C):
  - Cyclohexane: 850 g/L
  - Acetone: 690 g/L
  - Xylene: 600 g/L
  - Ethanol: 260 g/L
  - n-Octanol: 53 g/L
- Vapor pressure: 3.37×10^{-6} mmHg at 25°C
- Octanol/water partition coefficient: 166 (log P_{ow} = 2.2)
- Henry's law constant: 1.95×10^{-9} atm•m^3/mole at 22°C

Formulations and Labeled Uses

Four methidathion products were registered in California as of April 2004, all by Gowan Company (Table 1). These products include two 25% active ingredient (AI) wettable powder (WP) and two 24.4% AI emulsifiable concentrate (EC) products. Both WP products are packaged in water-soluble packaging (WSP). EC products have multiple packaging types, which include WSP. For EC products, each pint of liquid is equivalent to ¼ lb AI; thus, one gallon equals 2 lbs AI. All products are classified by U.S. EPA as restricted-use pesticides due to concern about residue effects on avian species (Title 40 Code of Federal Regulations (CFR), Section 152.170), and are listed as restricted-use pesticides under California regulations as well (Title 3 Code of California Regulations (CCR), Section 6400).

Registered uses are as an insecticide and miticide on various crops, including citrus, stone, and pome fruits, nuts, artichokes, olives, safflower, sunflower, cotton, and ornamental plants (nursery stock only). Special Local Needs uses (Section 24c) have been registered in California for clover and alfalfa (grown for seed only), kiwifuit, and several citrus fruits.

Table 1. Methidathion Products Currently Registered in California

Product Name	Formulation Class	Percent AI	USEPA Reg. No.
Supracide® 25W Insecticide-Miticide	Wettable powder	25	10163-244
Supracide® 25 WP Insecticide-Miticide	Wettable powder	25	100-754-10163
Supracide® 2E	Emulsifiable Concentrate	24.4	10163-236-AA
Supracide® 2E Liquipac	Emulsifiable Concentrate	24.4	10163-236-ZA

Pesticide Application and Use

Table 2 summarizes methidathion use in California for the five year period, 1998-2002 (DPR, 2000a; 2000b; 2001; 2002; 2003). In addition to providing total applications to all crops, Table 2 lists applications to several of the crops where usage was greatest. Crops are listed in Table 2 in descending order, based on pounds AI applied in 2002.

Use of methidathion decreased on all crops substantially during the five-year period (Table 2). For many crops, the largest decrease in that interval occurred between 1999 and 2000. Although DPR's Pesticide Use Report does not explain changes in use (e.g., no information is given about pests being treated), for many crops listed in Table 2 information is available elsewhere that may at least partly explain changes in pesticide use. For example, in cotton methidathion use decreased to less than 100 lbs AI each year after 1998, and no use was reported in 2002 (methidathion is still registered for use in cotton in California). In recent years, increased use of genetically modified cotton has been shown to correlate with fewer pesticide applications in southern California (Epstein and Bassein, 2003); growers switching to genetically modified cotton might explain part or all of the decreased methidathion use in that crop. In cotton as well as in other crops, it is also possible that other pesticides have substituted for methidathion. Several pests against which methidathion may be used, including lygus bug in cotton and California red scale in citrus, now have populations in the state that are resistant to methidathion and other OPs (UC IPM, 2004). In almonds, many growers have switched from OPs to pyrethroids for dormant season applications, due to concerns about surface water contamination with OPs (Epstein and Bassein, 2003; Zhang *et al*., 2004).

Table 2. Methidathion Use in California from 1998 through 2002 [a]

Crop	1998		1999		2000		2001		2002	
	Lbs AI	%	Lbs AI	%	Lbs AI	%	Lbs AI	%	Lbs AI	%
Citrus	20,779	11.6	36,192	20.4	6,972	7.1	20,147	21.7	16,040	23.6
Artichokes	15,336	8.6	15,169	8.6	15,331	15.6	14,285	15.4	11,920	17.6
Almonds	60,115	33.7	52,820	29.8	25,120	25.6	23,105	24.8	10,974	16.2
Peaches	12,225	6.9	12,328	6.9	13,504	13.8	7,386	7.9	5,605	8.3
Nectarines	6,196	3.5	6,776	3.8	3,176	3.2	2,405	2.6	3,117	4.6
Walnuts	15,163	8.5	11,263	6.3	5,130	5.2	3,115	3.3	2,879	4.2
Prunes	11,655	6.5	5,381	3.0	7,454	7.6	3,668	3.9	2,073	3.1
Plums	13,250	7.4	11,831	6.7	10,568	10.8	7,981	8.6	1,636	2.4
Safflower	3,455	1.9	2,188	1.2	212	0.2	664	0.7	613	0.9
Nursery	705	0.4	811	0.5	368	0.4	408	0.4	376	0.6
Cotton	572	0.3	46	0.0	32	0.0	61	0.0	0	0.0
Misc. crops [b]	21,500	12.0	24,313	13.7	11,151	11.4	14,068	15.1	12,650	18.6
All crops	178,451	100	177,406	100	98,129	100	93,055	100	67,833	100

[a] Expressed as lbs active ingredient (AI), and as percent of total methidathion use for each year (DPR, 2000a; 2000b; 2001; 2002; 2003).

[b] Includes crops such as olives, apples, alfalfa, pears, apricots, cherries, etc.

In spite of the trend of decreasing methidathion use in recent years, there is no mechanism in place to prevent increased use in the future. Because of this, decreased use documented in a single year (e.g., 2002) was not considered to be necessarily representative of future methidathion use for purposes of estimating exposure. Although use was substantially lower in 2002 than in previous years, exposure estimates in this EAD rely on five-year average use patterns rather than data from any single year. However, data from these years represent lower use than in several previous years. The highest reported annual use of methidathion (since 1990, when use reporting began) was 451,826 lbs in 1993 (DPR, 2000a). This is more than double the use in 1998, and is more than six times the use reported in 2002 (Table 2).

In 1998 – 2002, methidathion use was most prevalent in the San Joaquin and Sacramento valleys, which are regions where tree crops are abundant. This use pattern can be seen in Table 3, which lists for each of four high-use crops, the three counties having the greatest methidathion use (lbs AI applied) in 2002. Nut crops (e.g., almonds) are mostly grown in the southern San Joaquin and the northern Sacramento valleys. Deciduous fruits (peaches, plums) grow throughout the San Joaquin and Sacramento valleys. Citrus crops are grown primarily in the warmer, drier, southern San Joaquin valley. In contrast, artichokes are grown in the cool, well-drained soils of the central and southern coasts.

Table 3. Counties with Greatest Reported Methidathion Use on Selected Crops in 2002 [a]

Use Site	County (percent of total methidathion use on that crop in 2002) [b]			Total in listed counties [c]
Citrus	Tulare (64.7)	Fresno (18.1)	Kern (14.0)	96.8
Artichokes	Monterey (99.9)	Santa Barbara (0.1)	No other county	100.0
Almonds	Kern (76.0)	San Joaquin (9.5)	Glenn (5.4)	90.9
Peaches	Fresno (26.9)	Sutter (16.0)	Tulare (14.5)	57.4

[a] Five leading counties based on total reported use (lbs AI in each county) in 2002 (DPR 2004; query run March 24, 2004).
[b] Percent of total lbs used in state.
[c] Sum of percent use in top three counties.

Methidathion is applied using aircraft, ground boom sprayer, airblast sprayer, low-pressure handwand, and backpack sprayer. Chemigation (application through an irrigation system) is prohibited. Products may also be applied directly to the soil by injection, shank or chisel. The WP and EC products are registered for nearly identical uses, except that EC products may be used on sunflowers and nursery stock in California, whereas the WP products are not registered for those uses.

Application rates of the WP (Supracide® 25W and Supracide® 25WP) and EC products (Supracide® 2E and Supracide® 2E Liquipac) range from 0.25 to 5 lbs AI/acre. The application rate for most tree crops is 4 to 12 lbs of product (1 to 3 lbs AI) per acre per application, except for citrus fruit, which may receive up to 20 lbs of product per acre (5 lbs AI/acre). Application rates for row and field crops are lower, 2 to 4 lbs of product (0.5 to 1 lb AI) per acre. For deciduous fruit and nut trees, the product is diluted in a minimum of 20 and 50 gallons of water per acre for aerial and ground application, respectively. For citrus and olives, the product is diluted in a minimum of 20 and 400 gallons of water per acre for air and ground, respectively.

Generally, only one dormant application per season is made for the deciduous fruit and nut crops, and nursery stock including woody ornamentals and herbaceous plants. Artichokes may receive up to eight applications per year and safflower up to three. Citrus may receive applications anytime except during the bloom period or two weeks before harvest, with a maximum of two applications per growing season. Pre-harvest intervals range from 7 days for walnuts and 14 days for cotton, to 80 days for almonds. In artichokes and olives, applications are prohibited after bud formation.

Label Precautions

The WP and EC formulations of methidathion differ in acute toxicity, and require different personal protective equipment (PPE) and engineering controls. Supracide® 2E and Supracide® 2E Liquipac are category I pesticides and require the signal word "danger" on the label. Supracide® 25 W and Supracide® 25 WP are category II pesticides and carry the signal word "warning". The following safety clothing is required to be worn when mixing, loading or applying products containing methidathion: long-sleeved shirt and long pants, chemical resistant (for EC) or waterproof (for WP) gloves, shoes plus socks. Protective eyewear is required when handling EC products. Use in enclosed areas requires a respirator with either an organic vapor-removing cartridge and a prefilter approved for pesticides (prefix TC-23C), or a canister approved for pesticides (prefix TC-14G). A dust mask is required when handling WP outdoors except when a closed system is used. When EC formulations are handled outdoors, use of a dust/mist filtering respirator is required (but see below in the California Requirements section).

The restricted entry interval (REI) as stated on the label is 48 hours when methidathion is applied at $\leq$ 2 lbs AI/acre and 14 days when applied at > 2 lbs AI/acre (but see below under "California Requirements"). Additional PPE is required for early entry. Early entry that involves contact with treated surfaces requires that workers wear coveralls, for all products.

California Requirements

<u>**Closed System for Mixing/Loading**</u>

California regulations require the use of a closed system for workers mixing and loading liquid formulations of toxicity category I pesticides (3 CCR 6746). Thus, all EC formulations of methidathion require the use of a closed system for mixing and loading. Additionally, under California regulations, "Persons properly mixing pesticides packaged in water soluble packets are considered to be using a closed (mixing) system." (3 CCR 6738). All WP products are packaged in water-soluble bags, as are some EC products (Rosenheck, 1998c). Because of the legal requirement (for EC products) and the legal definition of water-soluble packaging as a closed system, in this EAD handlers were assumed to mix/load using a closed system.

<u>**Protective Clothing and Personal Protective Equipment**</u>

Handlers mixing/loading using a closed system are allowed by federal and state law to substitute alternate, usually less protective PPE for that listed on product labels. Under the federal Worker Protection Standard (40 CFR 170.240), "Persons using a closed system to mix or load pesticides with a signal word of DANGER or WARNING may substitute a long-sleeved shirt, long pants, shoes, socks, chemical-resistant apron, and any protective gloves specified on the labeling for handlers for the labeling-specified personal protective equipment." Additionally, under the Worker Protection Standard, "Persons using a closed system that operates under pressure shall wear protective eyewear."

The corresponding California regulations have more restrictive PPE requirements (3 CCR 6738): "Persons using a closed system to handle pesticide products with the signal word 'DANGER' or 'WARNING' may substitute coveralls, chemical resistant gloves, and a chemical resistant apron for personal protective equipment required by pesticide product labeling." Also, "Persons using a closed system that operates under positive pressure shall wear protective eyewear in addition to the personal protective equipment listed...Persons using any closed system shall have all personal protective equipment required by pesticide product labeling immediately available for use in an emergency."

As stated in the previous section, methidathion product labels specify that handlers must wear long-sleeved shirt and long pants, chemical resistant (for EC) or waterproof (for WP) gloves, shoes plus socks. Depending on the product and conditions of use, appropriate respiratory protection is required, and protective eyewear is required when handling EC products. However, neither coveralls nor a chemical apron is required. Coveralls and chemical resistant aprons provide substantial protection (Thongsinthusak *et al*., 1991); because of this, exposure estimates would be decreased if workers were assumed to wear coveralls and chemical resistant aprons. Both the federal Worker Protection Standard (40 CFR 170.240) and the corresponding California regulation (3 CCR 6738) state that PPE *may* be substituted; that is, substitution of PPE during use of a closed system is optional. Workers may legally wear protective clothing and PPE listed on products labels, and in this EAD all handlers were assumed to wear protective clothing and use PPE listed on product labels (see below, in Exposure Assessment section).

Reentry Interval

Methidathion applied to citrus has a longer REI, 30 days, under California law (3 CCR 6772); this extended REI has been required since 1976 and was incorporated into the exposure estimate for fieldworkers harvesting/thinning citrus. Exposure estimates for other crops used REIs specified on product labels.

Reported Illnesses

Reports of illness and injury with definite, probable, or possible exposure to pesticide products are recorded in a database maintained by the Pesticide Illness Surveillance Program (PISP) at DPR. The PISP database contains information about the nature of the pesticide exposure and the subsequent illness or injury. Between 1982 and 1999, a total of 109 incidents involving methidathion were reported to PISP (Mehler, 2001). No illnesses were reported in 2000 - 2002 (L. Mehler, pers. comm., March 24, 2004). Of the reported incidents, 30 were associated with exposure (or possible exposure) to methidathion only, and the remaining 79 followed exposure (or possible exposure) to methidathion in combination with other pesticides. Most of the illnesses were systemic in nature (81 of 109, or 74% of the total cases), with complaints of nausea, vomiting, abdominal cramps, headache, and dizziness (Mehler, 2001). The other 28 incidents consisted of injuries or irritation to eyes or skin. All but three of the incidents were occupational exposures, in which the subjects were working with or near methidathion (or multiple pesticides that included methidathion), or were working in treated areas. Of the individuals reporting illness following occupational exposures, 6 were mixer/loaders, 36 were applicators, and 13 were mixer/loader/applicators. Fifteen workers reported illness after entering a field treated with methidathion. Most of the other occupational exposures occurred when workers experienced drift from an application occurring nearby. Of the three non-occupational exposures, two involved residents living near application sites and one involved a cyclist accidentally sprayed while biking past an orchard. No deaths were associated with methidathion exposure. In an investigation of case reports of individuals with pesticide-associated illness between 1982 and 1990, methidathion was among ten organophosphates for which exposure was associated with cholinesterase inhibition in at least ten cases (O'Malley *et al.*, 1994).

Illness reports in the literature are limited to cases of ingestion (Teitelman *et al.*, 1975; Zoppellari *et al*., 1990; Tsatsatkis *et al*., 1996). Symptoms were generally consistent with organophosphate toxicity, and included substantial inhibition of cholinesterase activity when tested.

Significant Exposure Scenarios

U.S. EPA identified twelve major handler exposure scenarios for methidathion (Travaglini, 1999; U.S. EPA, 2001). Four of the scenarios involved aerial application: mixing/loading water-soluble packets, mixing/loading liquid formulations, fixed-wing aerial application, and flagging. Eight scenarios involved ground applications: mixing/loading water-soluble packets for groundboom applications, mixing/loading water-soluble packets for airblast applications, mixing/loading liquid formulations for groundboom applications, mixing/loading liquid formulations for airblast applications, groundboom sprayer application, airblast spray application, mixer/loader/applicator applying with a low-pressure handwand, and mixer/loader/applicator applying with a backpack sprayer.

In addition to the pesticide handler scenarios, U.S. EPA identified three groups of scenarios associated with post-application exposure (Travaglini, 1999; U.S. EPA, 2001). The first of these was scouting in cotton and safflower. The second was hoeing, irrigation, and other activities associated with artichokes. The third included harvesting and cultivation activities in tree crops such as citrus, kiwifruit, longan, and carambola.

Based on use instructions on current product labels, DPR identified scenarios that could result in significant worker exposure. For handlers, DPR identified nine potentially significant exposure scenarios. Three of the scenarios involved aerial application: mixing/loading, application, and flagging. Six scenarios involved ground applications: mixing/loading in support of groundboom applications, mixing/loading in support of airblast applications, groundboom sprayer application, airblast spray application, mixing/loading/applying with a low-pressure handwand, and mixing/loading/applying with a backpack sprayer.

In addition to handlers, reentry workers, bystanders, and the public also have the potential for exposure to methidathion. Based on information about cultivation activities in crops for which methidathion is registered, DPR identified three potentially significant reentry worker exposure scenarios. These included scouting in cotton and safflower, harvesting and thinning citrus, and thinning artichokes. Estimates generated for scouting in cotton were anticipated to also be the best estimates available for exposures during other fieldworker activities in cotton such as weeding, roguing, and harvesting.

Harvesting and thinning activities in reentry worker exposure scenarios prepared by DPR were limited to citrus trees, rather than all tree crops, as deciduous fruit and nut trees receive only dormant applications. As no foliar applications occur, worker exposure to pesticides in fruit and nut trees is expected to be minimal. Harvesting of artichokes also would not be expected to result in significant exposure to methidathion, as use occurs only in the interval between planting/cut-back and bud formation and no significant residues would be anticipated to be present at harvest.

Individuals might be exposed to methidathion if they are working adjacent to fields that are being treated or have recently been treated (bystanders). Also, airborne methidathion exposures to the public are possible in areas that are far from application sites (ambient air exposure). Ambient air and bystander exposures to airborne methidathion were estimated, based on monitoring studies of methidathion at application sites and in ambient air. Residential handler and reentry exposures are not anticipated to be significant, as methidathion has no registered uses in residential settings; all registered uses are agricultural. U.S. EPA concluded that residential exposure is limited to dietary and water (U.S. EPA, 2001). Exposures from water and diet are expected to be non-significant, based on evaluations by U.S. EPA (2001) and DPR (Lewis, 2001).

PHARMACOKINETICS

Dermal and Inhalation Absorption

No human dermal absorption (DA) studies were available during the preparation of this EAD, nor did U.S. EPA have access to DA studies while preparing the human health risk assessment for methidathion (U.S. EPA, 2001). DPR is aware of a single DA study, which used mice (Simoneaux and Marco, 1984). However, this study is considered unacceptable because organic solvents were used as vehicles (acetone and "petroleum hydrocarbon"), and because the study incorporated just a single dose. Organic solvents can influence absorption (U.S. EPA, 1996a), and use of a single dose provides insufficient information as DA may be dose-dependent (Thongsinthusak *et al*., 1999). U.S. EPA (2001) estimated the DA to be 30%, based on a comparison of oral and dermal toxicity in two studies using rabbits. Approximation of the DA by the ratio of oral to dermal toxicity studies is problematic because: 1) it depends on the assumption that all of the difference between oral and dermal lethal toxicity is due to DA, which may not be valid for most pesticides, 2) it depends on the assumption that 100% of an oral dose is absorbed, 3) toxicity studies use much higher doses than are typically of interest for DA and the ratio may not generalize to lower doses, and 4) dose determination in toxicity studies may not be sufficiently exact for determining DA. It is DPR policy not to use toxicity ratios to estimate DA. As no acceptable data are available, the DPR default value of 50% was used in this document for calculations of absorbed dermal doses. This default value is based on a review of DA of several chemicals, and is documented in Donahue (1996).

No inhalation absorption studies are available. In the absence of these data, a default inhalation absorption value of 100% was used for calculations of doses absorbed via inhalation.

Animal Metabolism

Metabolism of methidathion has been investigated in several mammals, including mice, rats, and cattle. Szolics (1987) investigated the fate of ^{14}C-methidathion in rats after a single oral dose and after feeding methidathion in the diet for two weeks. Although the two-week dietary study will not be discussed in this exposure assessment, it might be important in estimating tissue residues after a subacute ingestion of methidathion. In the single-dose oral study, ^{14}C-methidathion in a starch suspension was administered by oral gavage to two groups of ten rats (five male and five female); one group received 0.314 mg/kg and the other group 2.985 mg/kg (Szolics, 1987). Combined oral, fecal and urinary ^{14}C recovery was 98-102%. The major routes of excretion were urine and exhaled air; elimination by these routes was approximately equal (study means were 39.7% of dose recovered from urine and 39.3% recovered from exhaled air). Mean half-lives for ^{14}C were 9.2 $\pm$ 0.3 hours and 7.4 $\pm$ 0.3

hours for low-dose males and females, respectively, and 7.5 $\pm$ 0.6 hours and 8.9 $\pm$ 0.7 hours for high-dose males and females. Kinetics of metabolism and elimination were similar for males and females, and consistent with a one-compartment model (Szolics, 1987).

Several urinary metabolites were identified in four male rats receiving a single oral dose of ^{14}C-methidathion, including the sulfide, sulfoxide, sulfone, and desmethyl derivatives (Cassidy *et al.*, 1969). The sulfoxide metabolite was the dominant one, accounting for 52% of the radioactivity excreted in the first 24 hours after dosing.

The metabolism of methidathion was studied *in vitro* using subcellular liver fractions from rats and mice, with and without the addition of cofactors glutathione and NADPH (Chopade and Dauterman, 1981). Metabolism was similar between the two species' livers, with a major metabolite being desmethyl methidathion. Desmethyl methidathion was one of four water-soluble metabolites; the other three were cysteine, glutathione, and cysteinyl glycine conjugates of methidathion.

In addition to studies in rodents, a few investigations were done on metabolism in cattle. One study was published in the open literature, in which methidathion radiolabeled at the carbonyl carbon was administered to three four-year-old Holstein cows (Polan and Chandler, 1971). Doses were given in capsules daily for 16 – 31 days. As with rats, metabolism and excretion was rapid, and approximately equal amounts of radiolabel were excreted in the urine and exhaled air. Metabolites appeared in milk and totaled less than 2% of the administered radiolabel; most of these metabolites were non-extractable and were not identified, although a small proportion were identified as sulfoxide and sulfone metabolites. Methidathion was not detected in milk (Polan and Chandler, 1971).

ENVIRONMENTAL CONCENTRATIONS

Air

California has laws that limit ambient air concentrations of pesticides, including the Toxic Air Contaminants Act (California Health and Safety Code, Sections 39650-39761), which codified the state program to evaluate and control toxic air contaminants (TAC). A pesticide is placed on the TAC list if its concentrations in ambient air have been determined to be within an order of magnitude of the concentration determined to cause human health effects (3 CCR 6890). Methidathion is a candidate for inclusion on the TAC list (Lee *et al.*, 2002). Methidathion concentrations have been monitored in the ambient air during peak application season and in the air surrounding application sites. These studies are discussed below. Additionally, a study done by DPR in January 1989 measured methidathion concentrations in fog water collected with an active sampler consisting of Teflon tubing and a pump, as well as in vegetation and on cards placed among crops (Turner *et al.*, 1989). Although Turner *et al.* (1989) did not monitor methidathion concentrations in air, the results of the study suggest that methidathion can be transported atmospherically for distances of at least 0.4 km. This study was done in Stanislaus County, in response to observations that residues of certain pesticides, including methidathion, were found on crops where they had not been used; these crops were adjacent to orchards where dormant spray pesticides, including methidathion, were used in winter. Methidathion concentrations were above the minimum detection limit in nearly all fog water samples, with estimated fog water in air concentrations (based on volume of fog in air sampled by the collection pump) ranging from 0.00008 to 0.00097 μg/m^3. Methidathion was also detectable in vegetation and card samples. As methidathion was not applied within 0.4 km of the sample sites, these results suggest that atmospheric transport occurred.

Ambient Air

In 1991, ambient air monitoring of methidathion and methidathion oxon concentrations was done in Tulare County under contract to the Air Resources Board (ARB) of the California Environmental Protection Agency (Royce *et al.*, 1993a). Tulare County was chosen for ambient air monitoring because it was the county with the most methidathion use. Samples were collected during a four-week interval, from June 27 through July 25, at four sites near anticipated methidathion applications, and at one background site.

The four ambient sites were all within 0.25 miles (0.16 km) of citrus groves, a major use site for methidathion, in the following locations: one at the Sunnyside Union Elementary School, Strathmore (Site S); one at Jefferson Elementary School, Lindsay (Site J); one at Exeter Union High School, Exeter (Site E); and one at the University of California Lindcove Field Station, Exeter (Site UC). The background site was the ARB Ambient Air Monitoring Station, Visalia (Site B). Except for Site UC, where the sampler was located 1.8 m above ground in an open area, all samplers were taken from rooftops 2-15 m above ground. Sample devices consisted of a glass tube containing two sections of XAD-2 resin (a 400-mg primary and 200-mg backup section) connected to a flowmeter and sampling pump with Teflon tubing; two resin tubes and flowmeters were connected to a very low flow sampling pump with nominal flow rate of 4 L/min (Royce *et al.*, 1993a).

Both methidathion and its oxidation product, methidathion oxon, were detected. Table 4 presents results for both analytes. In Table 4, samples below the limit of detection (LOD) were reported as ½ LOD. The LOD for methidathion was 0.01 $\mu g/m^3$, and the LOD for methidathion oxon was 0.03 $\mu g/m^3$. The reported values for samples below the LOD were 0.005 $\mu g/m^3$ and 0.015 $\mu g/m^3$, respectively. Most field and analytical spike recoveries were greater than 100% for both compounds, and methidathion oxon was detected in blank samples, suggesting matrix interference. A follow-up report on the overall sampling program attributed the elevated background in analysis of methidathion and methidathion oxon to the electron-capture detector used (Royce *et al.*, 1993b). Because methidathion oxon was detected in blank samples, results were not considered reliable and exposure estimates were not based on methidathion oxon concentrations reported by Royce *et al.* (1993a).

Methidathion concentrations ranged from below the LOD to 0.56 $\mu g/m^3$, and the oxon concentrations ranged from below the LOD to 0.12 $\mu g/m^3$ (Table 4). Whether applications actually occurred near the sampling sites during the sampling interval was not reported by Royce *et al.* (1993a); however, ARB practice was to confirm that applications occurred within 1 mile of the monitoring sites when most or all ambient air samples for an AI or its breakdown product were below the limit of quantitation (LOQ; Baker *et al.*, 1996). Including samples collected at Site B, methidathion concentrations were below the LOQ in 91% of the samples (LOQ = 0.03 $\mu g/m^3$), and methidathion oxon concentrations were below the LOQ in 97% of the samples (LOQ = 0.09 $\mu g/m^3$).

In 1996 and 1997, the U.S.G.S. monitored atmospheric concentrations of several pesticides, including methidathion, at three locations in Sacramento County (Majewski and Baston, 2002). Two of the sites were rural, at airports northwest and southeast of Sacramento (samplers were about 3 m above ground); the third site was in downtown Sacramento (about 10 m above ground). The rural sites were approximately 10 and 20 miles (16 and 32 km) northwest and southeast, respectively, of the downtown site. Sample devices consisted of 119-cm^3 polyurethane foam plugs (mean density = 0.043 g/m^3) in Teflon cartridges, connected to high-volume blowers flowing at approximately 100 L/min (Majewski and Baston, 2002). Weekly whole-air (particulates were not filtered out), composite samples were collected at each site throughout the study. Sampling was triggered when 15-min mean wind speeds were >1 m/sec in a northerly or southerly direction, and continued until the directional wind speed decreased below the trigger velocity; maximum sampling was 20 min/hr. Methidathion was detected just once at each of the rural sites (concentrations: 0.00035 and 0.00026 μg/m^3); both samples were collected in January, and when the wind was from the south. Methidathion was not detected in samples collected from the downtown Sacramento site (reporting level 0.00020 μg/m^3).

Table 4. Methidathion Concentrations in Ambient Air Monitoring in 1991 [a]

Date	Site S [b]		Site J		Site E		Site UC		Site B	
	MT [c]	MO [c]	MT	MO	MT	MO	MT	MO	MT	MO
June 27	0.027	0.042	0.32	0.035	0.019	0.043	0.014	0.075	0.005	0.041
July 1	0.024	0.060	0.018	0.051	0.005	0.037	0.005	0.055	0.013	0.039
July 2	0.005	0.070	0.018	0.11	0.028	0.12	0.005	0.062	0.012	0.066
July 3	0.005	0.033	0.012	0.015	0.012	0.015	0.005	0.015	0.005	0.015
July 4	0.005	0.026	0.011	0.033	NS [d]	NS	NS	NS	0.005	0.060
July 8	0.005	0.067	0.005	0.062	0.005	0.046	0.005	0.049	0.005	0.015
July 9	0.005	0.084	0.005	0.060	0.005	0.039	0.005	0.078	0.005	0.056
July 10	0.005	0.057	0.56	0.104	0.005	0.015	0.005	0.015	0.005	0.068
July 11	0.005	0.033	0.30	0.074	0.005	0.057	NS	NS	0.005	0.015
July 15	0.005	0.015	0.036	0.015	0.013	0.015	0.005	0.015	0.005	0.015
July 16	0.005	0.015	0.023	0.015	0.005	0.015	0.010	0.015	0.005	0.015
July 17	0.005	0.015	0.036	0.043	0.005	0.015	0.005	0.015	0.005	0.015
July 18	0.005	0.015	0.031	0.015	0.070	0.015	0.014	0.015	0.005	0.015
July 22	0.005	0.015	0.028	0.015	0.017	0.015	0.005	0.015	0.005	0.015
July 23	0.005	0.015	0.025	0.015	0.005	0.015	0.005	0.015	0.005	0.015
July 24	0.005	0.015	0.015	0.015	0.005	0.066	0.005	0.015	0.005	0.086
July 25	0.005	0.092	0.014	0.11	0.005	0.12	0.008	0.015	0.005	0.11
Mean [e]	0.011	0.039	0.086	0.046	0.013	0.041	0.007	0.031	0.006	0.039
SD [e]	0.009	0.027	0.156	0.035	0.017	0.035	0.003	0.025	0.002	0.030

[a] Monitoring at sites in Tulare County (Royce *et al*., 1993). Concentrations are reported in μg/m^3, and have not been corrected for background. For results below the limit of detection (LOD), ½ LOD was reported. LOD for methidathion: 0.01 μg/m^3. LOD for methidathion oxon: 0.03 μg/m^3.

[b] Site S: Sunnyside Union Elementary School, Strathmore. Site J: Jefferson Elementary School, Lindsay. Site E: Exeter Union High School, Exeter. Site UC: University of California Lindcove Field Station, Exeter. Site B: background site at the ARB Ambient Air Monitoring Station, Visalia.

[c] MT: Methidathion. MO: Methidathion oxon.

[d] NS: No sample on this date.

[e] Arithmetic mean and standard deviation (SD).

Application Site Air

Application site monitoring occurred in July 1991; air samples were collected before, during, and 46.5 hours following airblast application of methidathion to an orange grove (Royce *et al.*, 1993a). Three air monitoring stations were located approximately 25 m north, approximately 15 m southeast, and approximately 150 m southeast of the orchard (prevailing winds in the area were from the northwest). Sample devices consisted of a glass tube containing two sections of XAD-2 resin (a 400-mg primary and 200-mg backup section) connected to a flowmeter and sampling pump with Teflon tubing; two resin tubes and flowmeters were connected to a very low flow sampling pump with nominal flow rate of 1.85 L/min (Royce *et al.*, 1993a). Both methidathion and methidathion oxon were detected in the application monitoring samples. However, methidathion was below the LOD in 39% (7 of 18) of the application monitoring samples (LOD = 0.1 µg/sample), and methidathion oxon was below the LOD in 72% (13 of 18) of the samples (LOD = 0.25 µg/sample). In the first 24 hours, all samples were below the LOD for methidathion oxon; this is probably a consequence of the high background levels in the oxon assay.

Table 5 summarizes air concentrations during the monitoring periods. A time-weighted average (TWA) concentration was calculated for the first 24 hours, starting with the hour during which the application occurred (1:00 AM on July 11), and continuing through the sample collected from 3:00 to 9:30 PM on July 11 (i.e., samples 1 through 4; 20.5 hours of monitoring). This TWA value was used in estimating bystander exposures (see the Exposure Assessment section). Because of the high background levels found in analysis for methidathion oxon, only results of monitoring for methidathion are considered in the EAD.

Table 5. Methidathion Concentrations (µg/m^3) Near an Orange Grove Receiving an Application [a]

Date and time of monitoring	North [b]	Southeast 1 [b]	Southeast 2 [b]	Wind Speed [g]	Wind Direction
July 10, 1991, 1500-1600 [c]	< LOD [d]	< LOD	< LOD	5	NW
July 10-11, 1991, 2330-0900 [e]	0.33	< LOD	< LOD	1	SW
July 11, 1991, 0900-1100	0.86	< LOD	< LOD	4	SW
July 11, 1991, 1100-1500	1.40	< LOD	< LOD	4	W/SW
July 11, 1991, 1500-2130	0.82	1.25	0.28	3	NW
24-hour TWA [f]	0.88	0.48	0.17	NA	NA
July 11-12, 1991, 2130-0730	3.16	0.60	0.10	1	SW
July 12-13, 1991, 0730-0730	0.46	0.30	< LOD	3	SW/NW/E/S

[a] Data from Royce *et al.* (1993a). Concentrations were calculated by dividing total amount of methidathion in each sample by the volume of air sampled, and have not been corrected for background. Air sampling pumps were calibrated to run 1.85 L/min.
[b] The North station was 25 m, Southeast 1 station was 15 m, and Southeast 2 station was 150 m from the orchard.
[c] Background air monitoring before application.
[d] Below limit of detection (LOD = 0.1 µg/sample)
[e] Air monitoring during application; application started at 0100 and lasted 8 hours. Subsequent measures are post-application.
[f] Time-weighted average (TWA) concentration over first 24 hours, beginning with application at 1:00 AM and ending with sample completed 9:30 PM. Samples taken during the first 20.5 hours were used as an approximation for the 24-hour TWA. For < LOD samples, ½ LOD was used in calculations.
[g] Wind speed in miles/hour. NA: not applicable.

The highest methidathion concentrations occurred at the station 25 m north of the orchard; concentrations ranged from < LOD to 3.16 μg/m^3 (Table 5). At the station 15 m SE of the orchard, concentrations ranged from < LOD to 1.25 μg/m^3. At the station 150 m SE of the orchard, methidathion concentrations ranged from < LOD to 0.28 μg/m^3

Water

Methidathion residues have been detected during monitoring of surface waters (Kuvila and Foe, 1995; Ross *et al.*, 1996). Kuvila and Foe (1995) monitored concentrations of five organophosphates in the Sacramento and San Joaquin rivers in January and February 1993. The five pesticides, including methidathion, are used as dormant sprays and were anticipated to be applied during the monitoring period. In the Sacramento River, only diazinon and methidathion were detected after heavy February rainfall. The maximum concentration of methidathion measured was 0.212 μg/L (Kuvila and Foe, 1995). Methidathion was also detected in the San Joaquin River following rain events in January and February (diazinon and chlorpyrifos also were detected); the maximum concentration measured was 0.586 μg/L (Kuvila and Foe, 1995).

Ross *et al*. (1996) monitored concentrations of organophosphate and carbamate insecticides in the San Joaquin River during two consecutive winters in 1991-1992 and 1992-1993. Of 108 samples collected, 19% had detectable levels of methidathion; nearly all detections coincided with rain events. Concentrations ranged between 0.07 and 12.4 μg/L (Ross *et al.*, 1996).

Dislodgeable Foliar Residues

Dislodgeable foliar residue (DFR) is defined as the pesticide residue that can be removed from both sides of treated leaf surfaces using an aqueous surfactant. DFR residues are assumed to be the portions of an applied pesticide available for transfer to humans from leaf and other vegetative surfaces. Measurements of DFR can be used, along with an appropriate transfer factor (TF), to estimate the amount of pesticide adhering to clothing and skin surfaces following entry into a previously treated field. The DFR is reported as residue per leaf area (μg/cm^2). DFR studies were conducted following methidathion use on citrus, cotton, and alfalfa crops (Table 6). In the subsequent discussion, Day 0 refers to the day of application, Day 1 is the first post-application day, and subsequent post-application days are similarly identified. A general equation for calculating DFR at a given time is: $DFR_t = DFR_0 \times e^{-kt}$, in which e is the natural logarithm base; k is the slope of the log-linear, first-order dissipation curve; and t represents the time interval (days); an equivalent expression is $\ln DFR_t = \ln (DFR_0) - kt$ (Dong *et al*., 1992).

Hernandez *et al.* (1998) collected grab samples of DFR coinciding with worker reentry activities. Methidathion was detected in seven of 82 samples, at concentrations ranging from 0.003 to 0.014 μg/cm^2. These samples were collected during weeding of artichokes, (two of two samples contained methidathion), harvest of navel oranges (three of 46 samples), and harvest of peaches (two of 34 samples). Hernandez *et al.* (1998) intended to provide general information about pesticide exposures to reentry workers, and application information generally was unavailable for these data. Because of this, these data could not be used for fieldworker exposure estimates.

DFR studies following methidathion applications were done under a variety of conditions, and resulted in a range of dislodgeable residues and residue dissipation half-lives (Table 6). All available data from studies performed in the U.S. are reported in Table 6. Studies were evaluated for acceptability based on criteria described in Iwata *et al*. (1977) and U.S. EPA (1996b); for example, each acceptable study was performed under climate conditions typical of California growing season; there were no rain events during the study; samples were collected for several days extending at least through the REI; replicate samples were collected; residues were dislodged from leaf surfaces with a detergent solution (rather than an organic solvent); and the application rate was at or below the maximum stated on the product label for the crop (although application rates might not affect the dissipation rate, the relationship has not been studied for methidathion). DFR values used in exposure estimates were back-calculated from equations generated from study data (Andrews, 2000).

Table 6. Dissipation of Methidathion on Various Crops and Locations

Crop	Formulation [a]	Location	Application rate (lb AI/acre)	Initial DFR [b] (µg/cm²)	Half-Life (Days) [c]
Alfalfa [d]	EC	Arizona	1.0	1.45	1.0
Cotton [e]	EC	California	0.5	0.34	1.4
Cotton [f]	WP	California	1.0	1.62	2.8
Cotton [f]	WP	North Carolina	1.0	2.03	2.8
Cotton [f]	WP	Texas	1.0	2.86	1.5
Orange [g]	EC	California	2.5	1.45 [h]	3.0
Orange [g]	EC	California	4.7	1.36 [h]	4.4
Orange [i]	EC	California	3.75	0.56	1.6
Orange [i]	EC	California	7.50	1.10	1.5
Orange [j]	EC	Florida	1.1	0.29	7.5
Orange [k]	EC	California	10.0	2.80	2.7
Orange [l]	EC	California	1.87	0.10 [h]	10.2
Orange [m]	EC	California	1.5	0.93	5.6
Orange [m]	EC	California	1.0	0.54	5.6
Orange [n]	WP	California	5.0	2.55	2.9
Orange [n]	WP	California	5.0	2.24	2.0
Orange [n]	WP	Florida	5.0	2.28	0.8 [o]

[a] EC: emulsifiable concentrate; WP: wettable powder. All formulations were mixed with water.
[b] Measured on Day 0 (day of application), unless indicated otherwise.
[c] Half-life calculated from the following equation: $T_{1/2} = (\ln 0.5)/k$, where k is the slope of the linear regression generated from study data: $\ln DFR_t = \ln (DFR_0) - kt$ (Dong *et al.*, 1992).
[d] Hensley (1981a); application with tractor-driven ground boom sprayer.
[e] Hensley (1981c); aerial application
[f] Rosenheck (1998b); Data following third application with tractor-driven ground boom sprayer. Equation used to calculate DFR for worker exposure estimate on Day t: $\ln DFR_t = 0.525 - 0.2449\ t$ ($r^2 = 0.945$).
[g] Maddy (1976); application method not reported.
[h] Measured on Day 1 (first day post-application), rather than on Day 0.
[i] Iwata *et al.* (1979); application with ground boom sprayer.
[j] Thompson *et al.* (1979); study conducted during rainy season; hand-gun application.
[k] Hensley (1981b); first application with boom sprayer, second with speed sprayer.
[l] Maddy (1984a); application method not reported.
[m] Maddy (1984b); application method not reported.
[n] Rosenheck (1998a); Data following second airblast application. Equation used to calculate DFR for worker exposure estimate on Day t: $\ln DFR_t = 0.667 - 0.162\ t$ ($r^2 = 0.937$).
[o] Heavy rainfall followed second application.

A few of the studies monitored DFR of methidathion oxon in addition to methidathion (Thompson *et al.*, 1979; Maddy *et al.*, 1984a, 1984b). Dislodgeable residues of the oxon were generally one to two orders of magnitude lower than methidathion residues. The effect of oxon residues on worker exposure is unknown. Oxon metabolites of thioate and dithioate compounds such as methidathion are generally more toxic than the parent compounds (Murphy, 1986).

Cotton and Other Row Crops

Two studies performed in California estimated DFR of methidathion following applications to cotton. In the first study, methidathion in the EC formulation was aerially applied at 0.5 lbs AI/acre (Hensley, 1981c). The DFR was 0.34 μg/cm^2 at Day 0. Dislodgeable residue decayed to non-detectable levels (0.008 μg/cm^2) after seven days. The estimated half-life was 1.4 days.

In the second study, three ground boom spray applications of methidathion in the WP formulation were done at the maximum label rate of 1.0 lb AI/acre (Rosenheck, 1998b). Residue analyses indicated a rapid decline in the DFR over the 35-day monitoring period following the third application. The amount of dislodgeable methidathion was 1.62 μg/cm^2 after the final application. DFR decreased to less than the detection limit (0.0096 μg/cm^2) 21 days later. The estimated half-life was 2.8 days. Data from this study were used to estimate DFR in cotton in this document because the application rate (1.0 lb AI/acre) is the maximum label rate allowed in California. These data for DFR in cotton differ from those used by U.S. EPA (Travaglini, 1999), which were from studies done in North Carolina and Texas (Rosenheck, 1998b).

As discussed above, the equation for DFR dissipation has the form: $DFR_t = DFR_0 \times e^{-kt}$. Based on data collected from the California study, Rosenheck (1998b) obtained the following values for the constants: DFR_0 = 1.69 and k = 0.2449 (r^2 = 0.945). The resulting Equation 1 is shown below. The DFR at Day 2 (DFR_2) is of interest in the exposure assessment as the REI following application of methidathion to cotton is 48 hours, and by law, Day 2 is the earliest workers may enter without wearing protective clothing and PPE required for handlers. Using Equation 1, DFR_2 was estimated to be 1.04 μg/cm^2.

Equation 1. Calculation of Dislodgeable Foliar Residues on Cotton [a]

$$DFR_t = (1.69\mu g / cm^2)(e^{-0.2449t}) \quad \text{or} \quad \ln DFR_t = 0.525 - 0.2449t$$

[a] *DFR: Dislodgeable Foliar Residue. t: Days post-application.*

As no DFR data were available for fieldworkers in artichokes or safflower, DFR data from cotton were substituted. The REI for both crops is 2 days; as with cotton, the Day 2 DFR (DFR_2) was used in the exposure assessment for reentry tasks in these crops. Using Equation 1, DFR_2 was estimated to be 1.04 μg/cm^2.

Citrus

Numerous DFR studies have been conducted following methidathion use on orange trees. Of the studies performed in California, two (Maddy, 1976; Iwata *et al.*, 1979) provided too few DFR measurements, resulting in inadequate data. Four acceptable studies were available.

In the first study, the EC formulation was applied by growers to two sites in Fresno County, at the rates of 1.5 and 1.0 lbs AI/acre (Maddy, 1984b). At 8 hours post-application, the average DFR was 0.93 μg/cm^2 at the first site and 0.54 μg/cm^2 at the second. Estimated half-lives were 5.6 days at both sites. The second study was similar to the first, except that methidathion was applied to a single orange grove at the rate of 1.87 lbs AI/acre (Maddy, 1984a). At 24 hours post-application, the average DFR was 0.097 μg/cm^2; the estimated half-life was 10.2 days; and residues decayed to non-detectable levels (detection limit 0.0005 μg/cm^2) after 28 days.

In the third study, the EC formulation was applied at the elevated rate of 10 lbs AI/acre via ground boom sprayer and speed sprayers in Corona, California (Hensley, 1981b). The initial (Day 0) average DFR was 2.80 μg/cm^2; DFR decreased to 0.084 μg/cm^2 by Day 14. The estimated half-life was 2.7 days.

In the fourth study, two ground applications were done at the maximum label rate (5 lb AI/acre) of methidathion, using the WP formulation, at each of two sites in California (Rosenheck, 1998a). DFR declined rapidly over the 35-day monitoring period following the second application. The reported half lives were 2.9 and 2.0 days.

In these studies, half-life estimates ranged from 1.5 to 10.2 days. In general, longer half-life estimates tended to occur when the initial DFR measurements were low relative to the detection limits (e.g., Maddy, 1984b). The best data set was judged to be from Rosenheck (1998a); these were used in this document to estimate DFR in citrus. U.S. EPA used data from this same study (Travaglini, 1999).

A linear regression done on natural log-transformed data from Rosenheck (1998a) resulted in Equation 2 (r^2 = 0.937). The REI for citrus is 30 days, and the Day 30 DFR (DFR_{30}) was used in the acute exposure assessment for reentry tasks in citrus. Using Equation 2, DFR_{30} was estimated to be 0.015 μg/cm^2.

Equation 2. Calculation of Dislodgeable Foliar Residues on Citrus [a]

$$\ln DFR_t = 0.667 - 0.162\,t$$

[a] *DFR: Dislodgeable Foliar Residue. t: Days post-application.*

Other Residues

Post-application methidathion residues have been measured in and on fruit (Iwata *et al*., 1979; Carmen *et al*., 1981), as well as in soil (Iwata *et al*., 1979). Measured dislodgeable surface residues on oranges following applications of 3.6 to 5.6 lbs AI/acre ranged from 0.5 to 1.1 μg/cm^2 on Day 0, and from 0.01 to 0.04 μg/cm^2 on Day 30 (Iwata *et al*., 1979). Instead of dislodgeable surface residues, Carmen *et al*. (1981) measured concentrations of methidathion in chopped orange rinds extracted with acetone; oranges were collected following methidathion applications of 3.9 lbs AI/acre. Fruit samples were initially collected on the first post-application day, and average concentrations in the rinds were between 0.5 and 1.1 μg/g (Carmen *et al.*, 1981). Samples were collected on five additional occasions between Day 10 and Day 60, and methidathion concentrations in the rinds remained fairly constant. In contrast, methidathion concentrations in pulp of all samples were below 0.01 μg/g (Carmen *et al.*, 1981). Methidathion concentrations in soil samples collected by Iwata *et al.* (1979) following applications of 3.6 to 5.6 lbs AI/acre ranged from 500 μg/g immediately following application, to < 10 μg/g on Day 30 (Iwata *et al*., 1979). These residues on fruit and in soil may add to overall worker exposure; however, little information is available about non-foliar residues. Generally, such residues are anticipated to have insignificant contributions to worker exposure when compared to DFR (Popendorf and Leffingwell, 1982), and were not considered further in the exposure assessment.

EXPOSURE ASSESSMENT

Handler and reentry exposure estimates for workers in significant exposure scenarios are discussed in the following sections. In addition, public exposure to airborne methidathion was estimated, based on monitoring studies of methidathion at application sites and in ambient air.

For short-term exposures (i.e., those with durations of 7 days or less) the Worker Health and Safety (WHS) Branch estimates the highest exposure an individual may realistically experience while performing a label-prescribed activity. In order to estimate this "upper bound" of daily exposure, WHS generally uses the estimated population 95th percentile of daily exposure. A population estimate is used instead of a sample statistic because sample maxima and upper-end percentiles, in samples of the sizes usually available to exposure assessors, are both statistically unstable and known to underestimate the population values. The population estimate, on the other hand, is more stable because it is based on all the observations rather than a single value; moreover, it is adjusted, in effect, for sample size, correcting some of the underestimation bias due to small samples. A high percentile is estimated, rather than the maximum itself, because in theory, the maximum value of a lognormal population is infinitely large. In practice, exposures must be bounded because a finite amount of AI is applied. The use of a high percentile acknowledges that the assumed lognormal distribution is probably not a perfect description of the population of exposures, especially at the upper extremes. The population 95th percentile is estimated, rather than a higher percentile, because the higher the percentile the less reliably it can be estimated and the more it tends to overestimate the population value (Chaisson *et al.*, 1999).

To estimate intermediate- and longer-term exposures, the average daily exposure is of interest because over these periods of time, a worker is expected to encounter a range of daily exposures (i.e., WHS assumes that with increased exposure duration, repeated daily exposure at the upper-bound level is unlikely). To estimate the average, WHS uses the arithmetic mean of daily exposure. The arithmetic mean is used rather than the geometric mean or the median because, although it can be argued that geometric means better indicate the location of the center of a skewed distribution, it is not the center that is of interest in exposure assessment, but the expected magnitude of the long-term exposure. While extremely high daily exposures are low-probability events, they do occur, and the arithmetic mean appropriately gives them weight in proportion to their probability. (In contrast, the geometric mean gives decreasing weight as the value of the exposure increases, and the median gives no weight whatsoever to extreme exposures.) In most instances, the mean daily exposure of individuals over time is not known. However, the mean daily exposure of a group of persons observed in a short-term study is believed to be the best available estimate of the mean for an individual over a longer period.

Handlers

Exposure Monitoring

Several studies are available in which worker exposure to methidathion during handling was evaluated. Most of these studies involved applications to three crops, alfalfa, cotton, and citrus. None of these studies was acceptable, for reasons described below. Additionally, a single airblast application of methidathion to almonds was monitored (Wang *et al.*, 1987). However, the individual monitored in this study spilled methidathion during open pouring (a practice not allowed under existing laws), invalidating even limited use of data collected in this study for exposure assessment. Also, in a large monitoring study (Drevenker *et al*., 1991), workers applying three organophosphate insecticides, including methidathion, were monitored using serum paraoxonase and arylesterase activities and urine analysis for several dialkylphosphorus metabolites. The study was not designed to monitor exposure to any particular insecticide, and was not used in this exposure assessment.

A study of exposure during methidathion applications to alfalfa was performed in Arizona (Hensley, 1981a). The study site consisted of two 4-acre plots to which the EC methidathion formulation was applied using a ten-foot spray boom with TX-6 nozzles. Workers applied 1.0 lb AI/acre in 20 gallons of water (i.e., a total of 4.0 pounds AI was handled by each worker). Extrapolating the measured results to an 8-hour day, the estimate for the mixer/loader (M/L) in the open system was 140 μg/person/day (4.2 μg/lb AI handled); for M/L using the closed system, 330 μg/person/day (10 μg/lb AI handled); and for applicators, 1200 μg/person/day (38 μg/lb AI handled). The higher exposure to M/L working with a closed system was unexpected, and possibly was due to a spill on the hands (Hensley, 1981a). This study was unacceptable because of limited replication and short exposure durations, 15 minutes for M/L and 2 hours for applicators.

Worker exposure in cotton was measured during aerial applications of the EC methidathion formulation at the rate of 0.5 lb AI/acre to a site in El Centro, California (Hensley, 1981c). Applications were made to 20 acres containing 5-foot tall cotton plants, at 5-8 feet above the canopy; a total of 10 lb AI was handled by each of three workers (a mixer/loader, an applicator, and a flagger). The single application took approximately 10 minutes; although the mixing and loading times were not stated, they also are anticipated to be short. Estimated exposures were extrapolated to a full day, based on measurements made from this unreplicated study. Estimated exposures were 3.0, 2.7, and 2.3 μg of methidathion/day for applicators, M/L, and flaggers, respectively (0.038, 0.034, and 0.029 μg/lb AI handled). Three scouts entered the field on post-application Day 1 and Day 3, making three 6-minute trips into the field each time. Scouts were estimated to have exposures of 170 (Day 1) and 9.2 (Day 3) μg of methidathion/day. This study was unacceptable because of limited replication and short exposure durations.

Three studies monitored worker exposure during methidathion application to citrus (Hensley, 1981b; Maddy *et al*., 1983; Krieger *et al*., 1998). In the first study, worker exposure was measured during application of the EC formulation at 10 lbs AI/acre (Hensley, 1981b). One acre was treated by a tractor-mounted boom sprayer (a total of 10 lb AI was applied) and three acres by airblast application in 2000 gallons of water (a total of 30 lb AI was applied). Two M/L working for 55 and 130 minutes, and two applicators working for 195 and 200 minutes, were evaluated for potential exposure with patches placed on their work clothing. Exposures were estimated as 210 and 1300 μg/person/day for M/L (2.6 and 5.4 μg/lb AI handled) and 3900 and 8700 μg/person/day for applicators (48 and 36 μg/lb AI handled). No detectable levels of methidathion or of two metabolites occurred in worker urine (the detection limit for all three substances was 0.01 mg/L). The third urinary metabolite, S-2,3-dihydro-5-methoxy-2-oxo-1,3,4-thiadiazole, was found in each M/L in small quantities (0.04 and 0.06 ppm) at 12 and 24 hours. This study was unacceptable because of limited replication and short exposure durations.

In the second citrus study, a specially designed oscillating boom sprayer was used to apply the emulsifiable concentrate at the rate of 1.5 lbs AI/acre (Maddy *et al*., 1983). Pre-application samples showed high background methidathion residues, invalidating data collected during application.

The third citrus study was designed to compare exposure differences between two types of protective suits (Krieger *et al.*, 1998). Two applications of a WP formulation were made by mixer/loader/applicators (M/L/A) using airblast sprayers at a rate of 2.0 lbs AI/acre. Absorption of methidathion was estimated by analysis of collected urine for six dialkyl phosphates that are common metabolites of organophosphates. Methidathion itself was not measured, nor were important metabolites, such as sulfoxide and desmethyl methidathion, identified in animal metabolism studies (Chopade and Dauterman, 1981; Szolics, 1987). Thus, although relative methidathion exposure between workers using the two types of protective suits could be determined, this study was not designed to provide data for exposure assessments. This study was also unacceptable because of inadequate replication.

Exposure Estimates Using Surrogate Data

As no acceptable studies were available for assessment of handler exposure, estimates were derived using the Pesticide Handler Exposure Database, or PHED (PHED, 1995). PHED was developed by the U.S. EPA, Health Canada and the American Crop Protection Association to provide non-chemical-specific pesticide handler exposure estimates for specific handler scenarios. It combines exposure data from multiple field monitoring studies of different AIs. The user selects a subset of the data having the same or a similar application method and formulation type as the target scenario. The use of non-chemical-specific exposure estimates is based on two assumptions: (1) that exposure is primarily a function of the pesticide application method/equipment and formulation type and not of the physical-chemical properties of the specific AI; and (2) that exposure is proportional to the amount of AI handled.

PHED has limitations as a surrogate database (Versar, 1992). It combines measurements from diverse studies involving different protocols, analytical methods and residue detection limits. Most dermal exposure studies in PHED use the patch dosimetry method of Durham and Wolfe (1962); residues on patches placed on different parts of the body are multiplied by the surface area of the body part to estimate its exposure. These partial estimates are then summed to provide a total body exposure estimate. Some studies observed exposure to only selected body parts such as the hands, arms and face. As a consequence, dermal exposure estimates for different body parts may be based on a different set of observations. Further, for some handler scenarios, the number of matching observations in the PHED is so small that the possibility they do not represent the target scenario is substantial. Due to the degree of uncertainty introduced by PHED, WHS calculates upper confidence limits on the exposure statistics to increase the confidence in the estimates of exposure.

When using surrogate data to estimate short-term exposure, WHS uses the 90% upper confidence limit (UCL) on the 95th percentile. The confidence limit is used to account for some of the uncertainty inherent in using surrogate data and to increase our confidence in the estimate. (Confidence limits on percentiles, also called tolerance limits, are described by Hahn and Meeker (1991).) Estimating the confidence limit requires knowing the mean and standard deviation. PHED reports the mean of total dermal exposure, but only the coefficients of variation for separate body regions. Because the sample sizes per body region differ and because the correlations among body regions are unknown, the standard deviation of total dermal exposure cannot be calculated. In order to approximate the confidence limit for the 95th percentile, WHS makes the assumption that total exposure is lognormally distributed across persons and has a coefficient of variation of 100 percent. The approximation (Powell, 2002) uses the fact that in any lognormal distribution with a given coefficient of variation, the confidence limit for the 95th percentile is a constant multiple of the arithmetic mean. The value of the multiplier depends only on sample size. To use the approximation with PHED data, the multiplier corresponding to the sample size is used (for dermal exposure, the median number of observations over body regions is used). If the sample size is between 20 and 119, the multiplier is 4; if it is between 12 and 19, the multiplier is 5 (Powell, 2002). Sample sizes and multipliers used are shown in Appendices 1-8, and results of PHED subsets are summarized in Table 7. Handler exposure estimates are given in Table 8.

When using surrogate data to estimate intermediate or long-term exposure, WHS uses the 90% UCL on the arithmetic mean. The 90% UCL is used for the reasons listed in the previous paragraph. As with short-term exposure estimates based on PHED subsets, a multiplier corresponding to the median sample size over body regions is used. If the median sample size is greater than 15, the multiplier is 1 (Powell, 2002).

Table 7. Data Used in Estimates of Pesticide Handler Exposure

Work Task	App. [a]	Short-term Exposure [b] (µg/lb AI handled)			Long-Term Exposure [b] (µg/lb AI handled)		
		Dermal	Inhalation	Total [c]	Dermal	Inhalation	Total [c]
Aerial							
M/L [d]	1	91.8	0.138	46.0	36.6	0.055	18.4
Applicator	3	371	0.286	186	124	0.115	62.1
Flagger	4	152	0.080	76.1	38.0	0.020	19.0
Airblast							
M/L	1	91.8	0.138	46.0	36.6	0.055	18.4
Applicator	5	4,090	2.16	2,050	1,020	0.541	511
Groundboom							
M/L	1	91.8	0.138	46.0	36.6	0.055	18.4
Applicator	6	102	0.448	51.4	25.5	0.112	12.9
Backpack sprayer							
M/L/A [d]	7	133,000	10.5	65,500	44,400	3.51	22,200
Low-pressure handwand							
M/L/A [l]	8	9,510	13.7	4,770	3,170	4.56	1,590

[a] Appendix number for Pesticide Handlers Exposure Database (PHED) subset details.
[b] Calculated from surrogate data using PHED database and software (PHED, 1995). Appropriate protection factors were applied as explained in the text and listed in Appendices 1-8.
[c] Total Exposure (µg/lb AI handled) = [(dermal exposure)(0.5) + (inhalation exposure)(1.0)]
[d] M/L = mixer/loader. M/L/A = mixer/loader/applicator.

Aerial Applications

Aerial application exposure estimates assumed a closed system for M/L and that all handlers (M/L, applicators and flaggers) wore the clothing and PPE listed on product labels (see California Requirements section); this included long-sleeved shirt and pants, shoes plus socks, waterproof gloves, and a respirator. Applicators (pilots) are not required to wear gloves during an application (3 CCR 6738), and were assumed to wear no gloves (see Appendix 3). Open cockpits were assumed for pilots, as there is no requirement for closed cockpits during applications.

Table 8. Estimates of Pesticide Handler Exposure to Methidathion

Work Task	Acute ADD [a] (mg/kg/day)	SADD [b] (mg/kg/day)	AADD [c] (mg/kg/day)	LADD [d] (mg/kg/day)
Aerial [e]				
M/L [f]	1.15	0.459	0.038	0.020
Applicator	4.65	1.55	0.129	0.069
Flagger	1.90	0.476	0.040	0.021
Airblast [g]				
M/L	0.132	0.052	0.009	0.005
Applicator	5.85	1.46	0.243	0.130
Groundboom [h]				
M/L	0.158	0.063	0.010	0.006
Applicator	0.176	0.044	0.007	0.004
Backpack sprayer [i]				
M/L/A [f]	0.190	NA	NA	NA
Low-pressure handwand [j]				
M/L/A	0.0034	NA	NA	NA

[a] Acute Absorbed Daily Dosage (acute ADD) is an upper-bound estimate calculated from the short-term exposure estimate given in Table 7. Acres treated per day assumptions differed for each application method. Application rate is maximum rate on product labels, and differed for each application method. Body weight assumed to be 70 kg (Thongsinthusak et al., 1993). Calculation:
Acute ADD = [(short-term exposure) x (acres/day) x (rate lb AI/acre)]/(70 kg body weight).

[b] Seasonal Average Daily Dosage is a 90% upper confidence estimate calculated from the short-term exposure estimate given in Table 7. SADD is the daily dose estimated for the season, based on recent use patterns. Acres treated per day assumptions differed for each application method. Application rate is maximum rate on product labels, and differed for each application method. Body weight assumed to be 70 kg (Thongsinthusak et al., 1993). Calculation:
SADD = [(long-term exposure) x (acres/day) x (rate lb AI/acre)]/(70 kg body weight).

[c] Annual Average Daily Dosage = SADD x (annual use months per year)/(12 months in a year). Annual use estimates vary for each scenario.

[d] Lifetime Average Daily Dosage = AADD x (40 years of work in a lifetime)/(75 years in a lifetime).

[e] Estimate assumed a maximum application rate of 5 lb AI/acre. Assumed 350 acres treated/day. Estimated season for SADD is 1 month; estimated annual use is 1 month.

[f] M/L = mixer/loader. M/L/A = mixer/loader/applicator.

[g] Estimate assumed a maximum application rate of 5 lb AI/acre. Assumed 40 acres treated/day. Estimated season for SADD is 1month; estimated annual use is 2 months.

[h] Estimate assumed a maximum application rate of 3 lb AI/acre. Assumed 80 acres treated/day. Estimated season for SADD is 2 months; estimated annual use is 2 months.

[i] Estimated use: , containing 0.5 lb AI/100 gal (U.S. EPA, 2001). Total: 0.2 lb AI/day. Seasonal and annual exposures are not anticipated to occur. NA = Not applicable.

[j] Estimated use: 10 gal/day, containing 0.5 lb AI/100 gal (U.S. EPA, 2001). Total: 0.05 lb AI/day. Seasonal and annual exposures are not anticipated to occur.

As handling of WP products in WSP resulted in higher exposure estimates than handling of EC products in a closed system (compare Appendices 1 and 2), use of WP products was assumed. In estimating exposure of M/L handling liquid products, the PHED data set was generated using data from studies in which respirators were not used (Appendix 1), and a 90% protection factor was applied to the data set for use of a respirator (NIOSH, 1987). The same protection factor was applied to PHED results for pilots (Appendix 3). Two protection factors were applied to PHED results for flaggers (Appendix 4): a 90% protection factor was applied to hand exposure for use of gloves (Aprea *et al*., 1994), and a 90% protection factor was applied to inhalation exposure for use of a respirator (NIOSH, 1987). The protection factor for gloves was needed because the flagger PHED scenario with gloves gave results with insufficient numbers of high-quality observations, and the scenario used did not include gloves. Unlike pilots, flaggers are not exempted from wearing gloves under California law (3 CCR 6738).

Acute exposures were estimated using upper bound values as described above; estimates are summarized in Table 8. The acute exposure estimates were 1.15 mg/kg/day for M/L, 4.65 mg/kg/day for aerial applicators, and 1.90 mg/kg/day for flaggers. The corresponding ADDs estimated by U.S. EPA for workers wearing long-sleeved shirts, long pants, shoes and socks, and using respirators, were 0.251 mg/kg/day for M/L, 0.132 mg/kg/day for aerial applicators (pilots), and 0.302 mg/kg/day for flaggers (Travaglini, 1999).

To estimate intermediate and long-term exposures of workers involved in aerial applications of methidathion, temporal patterns were investigated by examining PUR data for the five year period, 1998 to 2002 (DPR, 2004). Numbers of sequential days with pesticide applications (and not more than two consecutive days in the interval without applications) were totaled for an estimate of seasonal exposure duration, and numbers of days per year were totaled for annual exposure estimates. In both cases, days were rounded to the nearest month. Data from the six counties with the most aerial methidathion applications were examined. These counties were grouped regionally; i.e., counties within each group are adjacent, and between each group there are counties with little or no aerial methidathion application. Three county groups were examined, and of these groups Butte and Sutter counties are northernmost; San Joaquin County is central; and Fresno, Kings and Tulare counties are southernmost. Fresno, Kings, and Tulare counties had the most sequential days with pesticide applications, 30 (1 month). The average days per year with pesticide applications in Fresno, Kings, and Tulare counties was 35 days per year. Based on these data, seasonal and annual exposures were both estimated to occur over 1 month.

Table 8 contains estimates of seasonal, annual, and lifetime exposures for pesticide handlers. Mixing/loading EC products for aerial applications has an estimated seasonal exposure (SADD) of 0.459 mg/kg/day for one month, an Annual Average Daily Dosage (AADD) of 0.038 mg/kg/day, and a Lifetime Average Daily Dosage (LADD) of 0.020 mg/kg/day. Exposure estimates for applicators are 1.55 mg/kg/day for one month (SADD), 0.129 mg/kg/day (AADD), and 0.069 mg/kg/day (LADD). Exposure estimates for flaggers are 0.476 mg/kg/day for one month (SADD), 0.040 mg/kg/day (AADD), and 0.021 mg/kg/day (LADD). U.S. EPA did not estimate seasonal, annual, or lifetime exposure for pesticide handlers, but calculated risk based on ADD only (Travaglini, 1999; U.S. EPA, 2001).

<u>Ground Applications, Airblast</u>

Significant exposure scenarios involving airblast applications are M/L and applicator. Airblast M/L/A were assumed to have exposures in the range of M/L and applicators (exposure estimates are normalized to an 8-hour day, and M/L/A would mix/load part of the day, and apply for the remainder). All M/L exposure estimates (in support of aerial, airblast, and groundboom applications) used the same surrogate PHED data, with the same clothing and PPE assumptions, and the same protection factors were applied to the PHED results. These assumptions and protection factors were discussed above in the aerial applications section. Airblast applicators were assumed to use clothing and PPE listed on product labels, for reasons stated in the California Requirements section. Airblast applicator scenarios used open cabs, as there is no requirement for closed cabs. For the applicator exposure estimate (Appendix 5), a 90% protection factor was applied to the inhalation exposure result for use of a respirator (NIOSH, 1987).

The acute exposure estimates were 0.132 mg/kg/day for M/L and 5.85 mg/kg/day for airblast applicators. The corresponding ADD estimated by U.S. EPA for M/L wearing long-sleeved shirts, long pants, shoes and socks, and using respirators, was 0.028 mg/kg/day (Travaglini, 1999). For airblast applicators, U.S. EPA estimated an ADD of 0.68 mg/kg/day dermal (assumed long-sleeved shirts, long pants, shoes and socks) and 0.0026 mg/kg/day inhalation (assumed use of respirator), for a total ADD of 0.683 mg/kg/day (Travaglini, 1999).

Airblast applications are common in tree crops, and for the purpose of estimating handler exposure all ground applications to these crops were assumed to be airblast applications. Temporal patterns were investigated by examining the most recent five years of PUR data (1998 to 2002) in the high-use counties of Fresno, Kern, and Tulare (DPR, 2004). These counties are adjacent to one another, and were considered together. Numbers of sequential days with pesticide applications (and not more than two consecutive days in the interval without applications) were totaled for an estimate of seasonal exposure duration, and numbers of days per year were totaled for annual exposure estimates. Small applications, defined as < 20 acres/day, were omitted on the assumption that these would be done by individual growers rather than professional applicators. There were as many as 35 sequential days with pesticide applications, and an average of 70 days per year. Based on these data, seasonal use of methidathion by workers involved in airblast applications is estimated to be one month, and annual exposure is estimated to occur over total of two months.

For M/L of WP products in support of airblast applications, SADD is estimated to be 0.052 mg/kg/day for one month, AADD is estimated at 0.009 mg/kg/day, and LADD is estimated at 0.005 mg/kg/day (Table 8). Exposure estimates for airblast applicators are 1.46 mg/kg/day for one month (SADD), 0.243 mg/kg/day (AADD), and 0.130 mg/kg/day (LADD).

Ground Applications, Groundboom.

Significant exposure scenarios involving groundboom applications are M/L and applicator. Groundboom M/L/A were assumed to have exposures in the range of M/L and applicators (exposure estimates are normalized to an 8-hour day, and M/L/A would mix/load part of the day, and apply for the remainder). All M/L exposure estimates (in support of aerial, airblast, and groundboom applications) used the same surrogate PHED data, with the same clothing and PPE assumptions; the same protection factors were applied to the PHED results. These assumptions and protection factors were discussed above in the aerial applications section. Applicators were assumed to use clothing and PPE listed on product labels, for reasons stated in the California Requirements section. The groundboom applicator scenario included use of either truck or tractor, and an open cab was assumed.

Two protection factors were applied to PHED results for applicators (Appendix 6): a 90% protection factor was applied to hand exposure for use of gloves (Aprea *et al*., 1994), and a 90% protection factor was applied to inhalation exposure for use of a respirator (NIOSH, 1987). The protection factor for gloves was needed because the applicator PHED scenario with gloves gave results with insufficient numbers of high-quality observations, and the scenario used did not include gloves.

The acute exposure estimate for M/L was 0.158 mg/kg/day (Table 8). For the applicator scenario, the acute exposure estimate was 0.176 mg/kg/day. U.S. EPA estimated ADD for M/L and groundboom applicators wearing long-sleeved shirts, long pants, shoes and socks, and using respirators, at 0.011 and 0.016 mg/kg/day, respectively (Travaglini, 1999).

Groundboom applications are common in row and field crops, such as alfalfa, artichokes, cotton, and safflowers. For the purpose of estimating handler exposure all ground applications to these crops were assumed to be groundboom applications. PUR data from Monterey County, where most ground applications to these crops occur, were examined from the five year period, 1998 – 2002 (DPR, 2004). Days in which fewer than 40 acres were treated (i.e., amounts taking less than 4 hours to treat) were not included, based on the assumption that these amounts would be treated by individual growers rather than professional applicators. There were as many as 65 sequential days with pesticide applications, and an average of 69 days per year. Based on these data, seasonal use of methidathion by workers involved in groundboom applications is estimated to be two months, and annual exposure is estimated to occur over total of two months.

For M/L of WP products in support of groundboom applications, SADD is estimated to be 0.063 mg/kg/day for three months, AADD is estimated at 0.010 mg/kg/day, and LADD is estimated at 0.006 mg/kg/day (Table 8). Exposure estimates for groundboom applicators are 0.044 mg/kg/day for three months (SADD), 0.007 mg/kg/day (AADD), and 0.004 mg/kg/day (LADD).

Applications with Backpack Sprayer

The significant exposure scenario for applications with a backpack sprayer is M/L/A. Workers in this M/L/A scenario were assumed to use clothing and PPE listed on product labels. A 90% protection factor was applied to inhalation exposure data for use of a respirator (NIOSH, 1987). The estimated acute ADD for M/L/A using backpack sprayers was 0.190 mg/kg/day (Table 8). U.S. EPA estimated a lower ADD, 0.007 mg/kg/day (Travaglini, 1999).

Backpack sprayers are versatile application tools that can be used in small acreages, spot spraying in locations that are difficult to reach with larger equipment, or in cases where larger equipment is unavailable (Landgren, 1996). In its exposure scenario, U.S. EPA assumed use primarily in applications to nursery stock, with a daily application of 40 gallons (Travaglini, 1999; U.S. EPA, 2001); these assumptions were also used by DPR as no better information was available.

For the purpose of estimating long-term handler exposure all ground applications to nursery stock were assumed to be backpack sprayer applications. PUR data from the five year period, 1998 to 2002, from the four counties with the most use (Fresno, Kern, Stanislaus and Tulare) were examined (DPR, 2004). Together, these counties accounted for 83% of ground applications of methidathion in nurseries statewide over the five-year period (the county with the greatest use, Kern County, had 45% of statewide use). Three of these counties (Fresno, Kern, and Tulare) are adjacent to one another, and were considered together; Stanislaus County was considered separately. Numbers of sequential days with pesticide applications (and not more than two consecutive days in the interval without applications) were totaled for an estimate of seasonal exposure duration, and numbers of days per year were totaled for annual exposure estimates. In all counties, days totaled much less than one month. There were never more than four sequential days with pesticide applications in any year. In Fresno, Kern, and Tulare counties, applications occurred an average of 11 days per year; in Kern County alone, the annual average was nine days. In Stanislaus County, methidathion applications averaged just four days per year. Based on these data, seasonal and annual exposures are not anticipated to occur for handlers involved in methidathion applications using backpack sprayers.

Applications with Low-Pressure Handwand

The significant exposure scenario for applications with a low-pressure handwand is M/L/A. Workers in this M/L/A scenario were assumed to use clothing and PPE listed on product labels. A 90% protection factor was applied to inhalation exposure data for use of a respirator (NIOSH, 1987). The estimated acute ADD for M/L/A using low-pressure handwands was 0.0034 mg/kg/day (Table 8). U.S. EPA estimated a lower ADD, 0.00031 mg/kg/day (Travaglini, 1999).

The significant exposure scenario for low-pressure handwand M/L/A was assumed to be in nursery stock, which is in agreement with the U.S. EPA assumption (Travaglini, 1999; U.S. EPA, 2001). As with backpack sprayers, for the purpose of estimating exposure to handlers using low-pressure handwands all ground applications to nursery stock were assumed to have been made with low-pressure handwands. Obviously, the same applications could not all have been made with both methods; however, in the absence of other information no better assumption can be made. As with handlers using backpack sprayers, seasonal and annual exposures are not anticipated to occur.

Fieldworkers

Significant exposure scenarios for reentry workers are assessed below. For each of these scenarios, exposures of workers reentering fields treated with methidathion were estimated from methidathion DFR on the same or surrogate crops. Transfer factor (TF) estimates were based on the crop and the activity of the worker. The absorbed daily dosage (ADD) was calculated as shown in Equation 3 (Zweig *et al*., 1980; Zweig *et al*., 1985), using a dermal absorption rate (DA) of 50% (Donahue, 1996), a default exposure duration (ED) of 8 hours, and a default body weight (BW) of 70 kg (Thongsinthusak *et al*., 1993). Acute exposure estimates for fieldworkers are summarized in Table 9. Seasonal, annual, and lifetime exposure estimates are summarized in Table 10.

Equation 3. Calculation of Absorbed Daily Dosage from Plant Surface Residues [a]

$$ADD\ (\mu g/kg/day) = \frac{DA \times DFR\ (\mu g/cm^2) \times TF\ (cm^2/hr.) \times ED\ (hrs./day)}{BW(kg)}$$

[a] ADD: Absorbed Daily Dosage. DA: Dermal Absorption Rate. DFR: Dislodgeable Foliar Residue. TF: Transfer Factor. ED: Exposure Duration. BW : Body Weight.

Reentry workers are not required to wear PPE unless entering before expiration of the REI. As much reentry work occurs in hot weather and for several hours each day, PPE is often not worn by fieldworkers. Therefore, fieldworker exposure calculations were not corrected with any protection factor. Acute exposures were estimated at the expiration of the REI for all activities (Table 9). For longer-term exposure estimates it was assumed that workers would not always enter fields at the expiration of the REI. Seasonal, annual and lifetime exposures were estimated at an assumed average reentry of REI + 7 days for cotton scouts and artichoke thinners, and REI + 10 days for workers harvesting or thinning citrus (Table 10). These assumed averages were not based on data; rather, they were based on the reasonable, conservative assumption that workers may enter fields an average of 7 - 10 days after expiration of the REI.

Studies of reentry worker exposure in crops treated with methidathion (Hensley, 1981c), as well as with other organophosphates (Ware *et al*., 1973, 1974, 1975; Popendorf *et al*., 1979), suggest that inhalation is a relatively minor exposure route. U.S. EPA also concluded that inhalation exposure of reentry workers would be negligible (Travaglini, 1999). Only dermal exposure was considered for fieldworkers.

Scouting in Cotton and Safflower

Cotton and safflower scouts are subject to occupational exposure from contact with dislodgeable methidathion residues that have accumulated on treated foliage. The REI is 48 hours for both crops. In the absence of adequate exposure data for workers entering treated fields, residue decay data and transfer factors were used to estimate worker exposure at expiration of the REI (Table 9). DFR was estimated based on a study done in cotton in California (Rosenheck, 1998b), as discussed above in the section on DFR. Transfer factors were derived from a series of studies in which several organophosphates were applied to cotton (Ware *et al*., 1973, 1974, 1975). Geometric mean transfer factors were computed for bare hands (950 cm^2/hr), the clothed upper body (102 cm^2/hr), and the clothed lower body (964 cm^2/hr). The potential dermal transfer factor for the whole body of cotton scouts (2,000 cm^2/hr) was calculated by summing these individual geometric mean transfer factors (Dong, 1990). The acute ADD for cotton/safflower scouts was estimated to be 0.119 mg/kg/day.

Table 9. Acute Exposures to Methidathion Estimated for Reentry Workers

Exposure scenario	DFR (µg/cm^2) [a]	TF (cm^2/hr) [b]	Acute ADD (mg/kg/day) [c]
Scouting in Cotton/Safflower [d]	1.04	2,000	0.119
Harvesting/Thinning Citrus [e]	0.015	3,000	0.0026
Thinning of Artichokes [f]	1.04	300	0.018

[a] Dislodgeable foliar residue (DFR) estimated for appropriate restricted entry interval (REI).
[b] Transfer factor (TF) is residue transferred to skin.
[c] Acute Absorbed Daily Dosage (Acute ADD) calculated from Equation 3. Assumptions include:
- Exposure duration = 8 hr
- Dermal Absorption = 50% (Donahue, 1996)
- Body weight = 70 kg (Thongsinthusak, *et al*., 1993)

[d] REI = 48 hours. DFR derived from Rosenheck (1998b). TF from Dong (1990).
[e] REI = 30 days. DFR derived from Rosenheck (1998a). TF from U.S. EPA (2000).
[f] REI = 48 hours. DFR (surrogate, cotton) derived from Rosenheck (1998b). TF from U.S. EPA (2000).

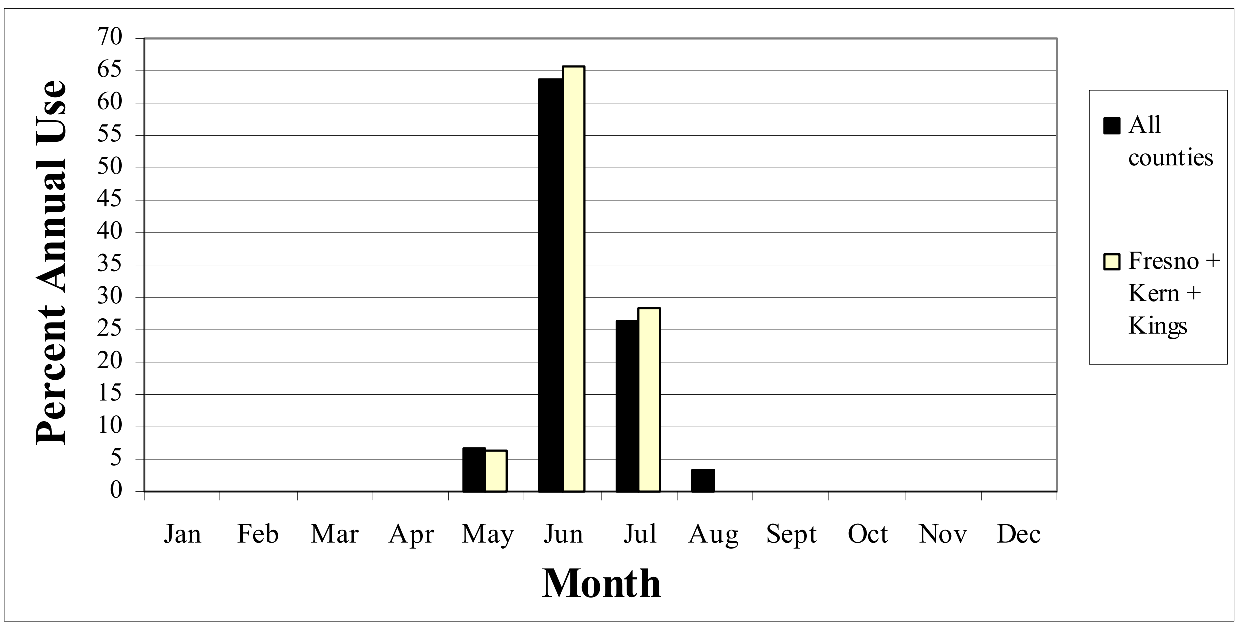
Figure 1 shows the relative numbers of cotton and safflower acres treated with methidathion, averaged on a monthly basis for the five year period, 1998-2002 (DPR 2004; queried April 22, 2004). Applications made in the entire state (all counties) are plotted in Figure 1, as are applications in the high-use counties of Fresno, Kern, and Kings. These counties are adjacent to one another, and examination of Figure 1 shows that the use pattern in these counties is very similar to the state of California as a whole. In these three counties, most applications occurred in late spring and early summer, with 66% of all applications occurring in June; all applications occurred between May and July. For seasonal and annual exposure estimates, it was assumed that scouts were exposed on each workday for these three months. The SADD was estimated to be 0.0214 mg/kg/day, the AADD was estimated to be 0.0053 mg/kg/day, and the LADD was estimated at 0.0028 mg/kg/day (Table 10).

Table 10. Estimates of Reentry Worker Exposure to Methidathion

Exposure scenario	SADD (mg/kg/day) [a]	AADD (mg/kg/day) [b]	LADD (mg/kg/day) [c]
Scouting in Cotton/Safflower [d]	0.0214	0.0053	0.0028
Harvesting/Thinning Citrus [e]	0.0014	0.0006	0.0003
Thinning Artichokes [f]	0.0032	0.0008	0.0004

[a] Seasonal Average Daily Dosage is a mean estimate of absorbed dose, calculated from Equation 3. DFR estimates are given below for each scenario. Transfer factors are listed in Table 9.
[b] Annual Average Daily Dosage = ADD x (annual use months per year)/(12 months in a year).
[c] Lifetime Average Daily Dosage = AADD x (40 years of work in a lifetime)/(75 years in a lifetime).
[d] DFR (Day 9) = 0.187. Estimated seasonal exposure is 3 months; estimated annual exposure is 3 months.
[e] DFR (Day 40) = 0.008. Estimated seasonal exposure is 5 months; estimated annual exposure is 5 months.
[f] DFR (Day 9) = 0.187. Estimated seasonal exposure is 3 months; estimated annual exposure is 3 months.

Figure 1. Applications of Methidathion to Cotton and Safflower in Selected Counties, 1998 – 2002 [a]



[a] Percent calculations based on acres treated (DPR, 2004; queried April 22, 2004).

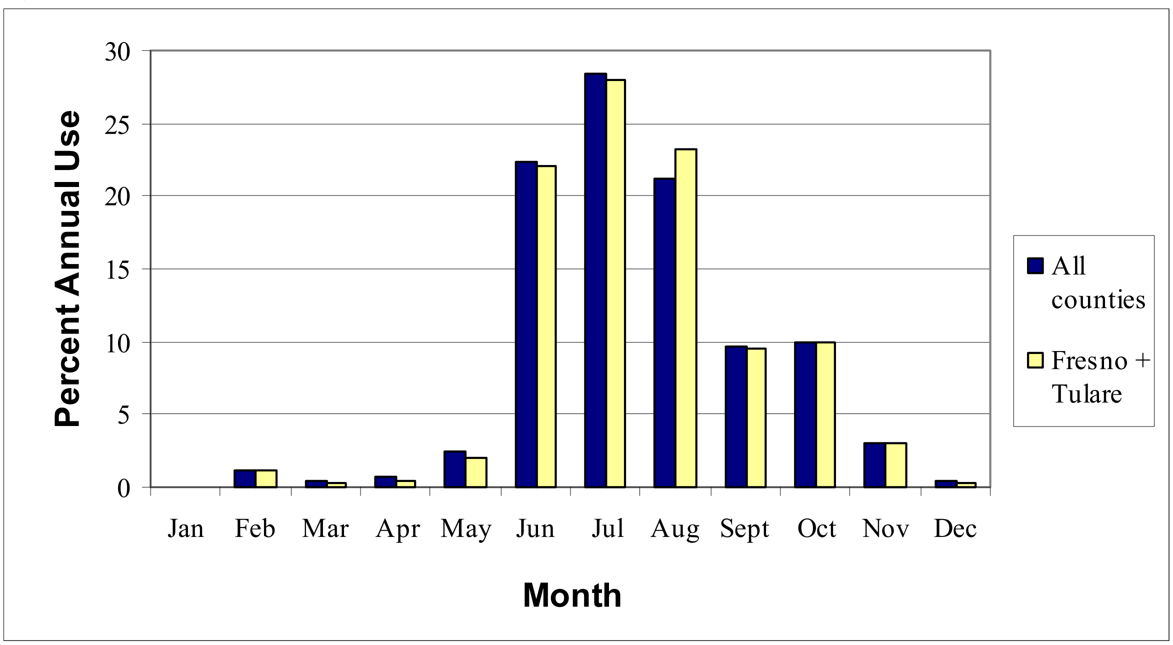
U.S. EPA estimated exposure of cotton and safflower scouts using DFR data from a study done in cotton in North Carolina and Texas (Rosenheck, 1998b). These data were chosen by U.S. EPA because DFR dissipated more slowly at sites in these states than at a site in California, resulting in more conservative exposure estimates (Travaglini, 1999). Reentry into early-season cotton at Day 2 post-application was estimated by U.S. EPA to result in a dermal dose in the range of 0.14-0.59 mg/kg/day (Travaglini, 1999). With respect to long-term exposures, U.S. EPA stated that such exposures were not reasonable, as scout exposure to foliage treated with methidathion was never likely to exceed 7 days (Travaglini, 1999).

Harvesting in Citrus

Under California law, the REI following applications to citrus is 30 days (3 CCR 3772). The maximum application rate of methidathion to citrus is 5.0 lbs AI/acre. In the absence of adequate exposure data for workers entering treated fields, residue decay data and transfer factors were used to estimate worker exposure at the expiration of the REI (Table 9). DFR data from a study done in California were used (Rosenheck, 1998a), and a transfer factor of 3,000 was used (Dawson, 2003). The acute ADD was estimated to be 0.0026 mg/kg/day.

Figure 2 summarizes numbers of citrus acres treated with methidathion, averaged on a monthly basis for the five year period, 1998-2002 (DPR 2004; queried April 24, 2004). Applications made in the entire state (all counties) are plotted in Figure 2, as are applications in the high-use counties of Fresno and Tulare. These two counties are adjacent to one another, and examination of Figure 2 shows that the use pattern in these counties is very similar to the state of California as a whole. Within the two high-use counties during the five-year period considered, the majority of the use (73%) occurred in June through August; in the entire state, 72% of the annual use occurred in those three months. The high-use period (>5% of annual use in each month) occurred in the five-month interval of June through October.

Figure 2. Total Applications (All Methods) of Methidathion to Citrus, 1998 – 2002 [a]



[a] Percent calculations based on acres treated (DPR 2004; queried April 23, 2004).

These data were compared to the task-specific data on cultivation activities in oranges that were available in the California Farm Worker Activity Profile database (CFWAP; Edmiston *et al.*, 1999). Within CFWAP, data were available on citrus (grapefruit, lemon and orange) harvesting in four counties in the San Joaquin Valley; data on oranges from Fresno and Tulare were used. Harvesting of oranges occurs year-round, with peak intervals in

January – February and June – August in Fresno County, and peak intervals in January – April and June – September in Tulare County (Edmiston *et al.*, 1999). Because harvesting oranges is done year-round, it suggests that worker exposure to methidathion may occur during the five months (June – October) when methidathion is applied most often. Based on these data, seasonal exposure to methidathion by citrus harvesters is estimated to be 0.0014 mg/kg/day for 5 months. The estimated annual exposure (AADD) was 0.0006 mg/kg/day, and the estimated lifetime exposure (LADD) was 0.0003 mg/kg/day (Table 10).

Thinning of Artichokes

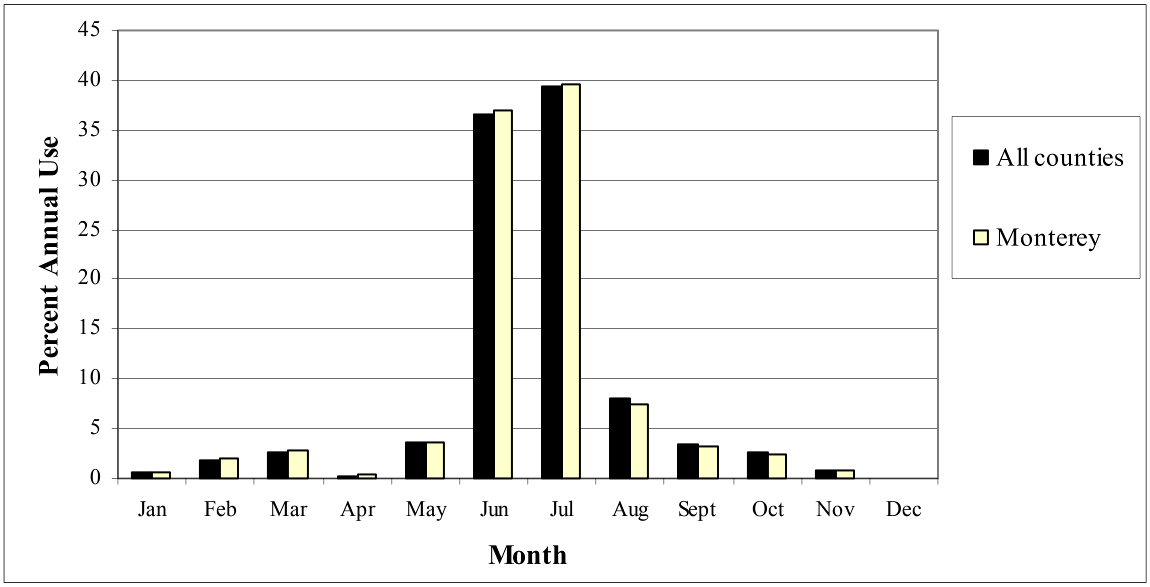
In artichokes, thinning was the only reentry activity considered to have the potential for significant methidathion exposure. As stated in the Significant Exposure Scenarios section, harvesting of artichokes would not be expected to result in significant exposure to methidathion, as use occurs only in the interval between planting/cut-back and bud formation. Thinning of artichokes requires relatively low foliage contact compared to other crops (U.S. EPA, 2000). In the absence of adequate exposure data for workers entering treated fields, residue decay data and transfer factors were used to estimate worker exposure at the expiration of the REI (Table 9). The default transfer factor of 300 was used to estimate fieldworker exposure (U.S. EPA, 2000). No DFR data were available for methidathion applied to artichokes; a surrogate DFR was used based on data from cotton (Rosenheck, 1998b). The acute ADD was estimated at 0.018 mg/kg/day (Table 9).

According to the product labels, methidathion may be applied up to eight times per season to artichokes. Applications can begin in newly-planted fields, and continue until buds appear. Worker activity data for cultivation activities in artichokes are not available in the CFWAP database (Edmiston *et al.*, 1999). However, publications describing cultivation practices are available (e.g. De Vos, 1992). Artichokes may be cut back any time of the year (De Vos, 1992); thus, workers may reenter fields anytime throughout the year.

Figure 3 summarizes applications of methidathion to artichokes in Monterey County and statewide, based on mean numbers of acres treated each month for the five year period, 1998-2002 (DPR 2004; queried April 22, 2004). In Monterey County, the majority of use (an average total of 77%) occurred in June and July; the high-use period (>5% of annual use in each month) occurred in the three-month interval of June through August (Figure 3).

Seasonal exposure was estimated to be 0.0032 mg/kg/day for 3 months. Annual exposure duration also was estimated to be 3 months. The AADD estimate was 0.0008 mg/kg/day, and the LADD was estimated at 0.0004 mg/kg/day (Table 10).

Figure 3. Total Applications (All Methods) of Methidathion to Artichokes, 1998 – 2002 [a]



[a] Percent calculations based on acres treated (DPR 2004; queried April 22, 2004).

Ambient Air and Bystander Exposures

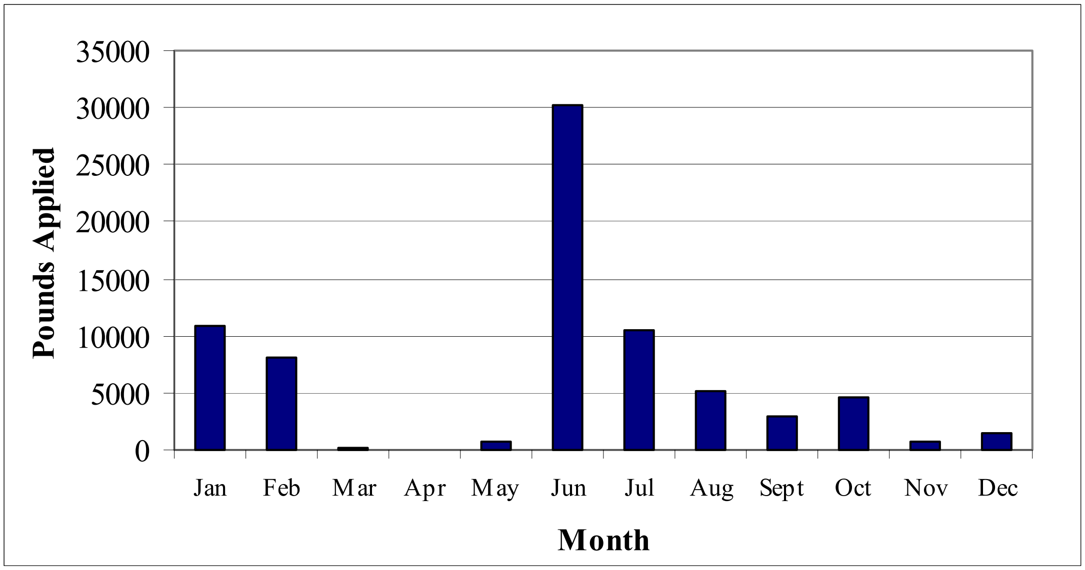
Ambient air and application site air monitoring detected methidathion, suggesting that the public may be exposed to airborne methidathion. Individuals might be exposed to methidathion if they are working adjacent to fields that are being treated or have recently been treated (bystander exposure). Also, air monitoring studies in Tulare and Sacramento counties suggest that airborne methidathion exposures are possible in areas that are far from application sites (ambient air exposure). Ambient air and bystander exposures are perhaps more likely in California than in other parts of the U.S. because of the close proximity of urban and agricultural areas in parts of the state where the greatest pesticide use occurs (CAST, 2002). Public exposure to airborne methidathion was estimated, based on monitoring studies of methidathion at application sites and in ambient air. See the Environmental Concentrations section for study details.

Ambient Air

Methidathion concentrations in ambient air were higher in Tulare County than in Sacramento County (Royce *et al*., 1993a; Majewski and Baston, 2002). This coincided with greater use in Tulare County than in Sacramento County; total annual use of methidathion was 75,582 pounds in 1991 in Tulare County and average annual methidathion use in Sacramento County in 1996 and 1997 was 533 pounds (see Figure 4 and Figure 5).

Whereas ambient air monitoring was done year-round in Sacramento County (Majewski and Baston, 2002), it was only done for four weeks in Tulare County, from June 27 through July 25 (Royce *et al*., 1993a). Figure 4 shows the use of methidathion in Tulare County in 1991, the year ambient air sampling was done in Tulare County. Examination of Figure 4 shows that the the highest use of methidathion in Tulare County in 1991 occurred during June, and that little use occurred in March, April, May, November and December.

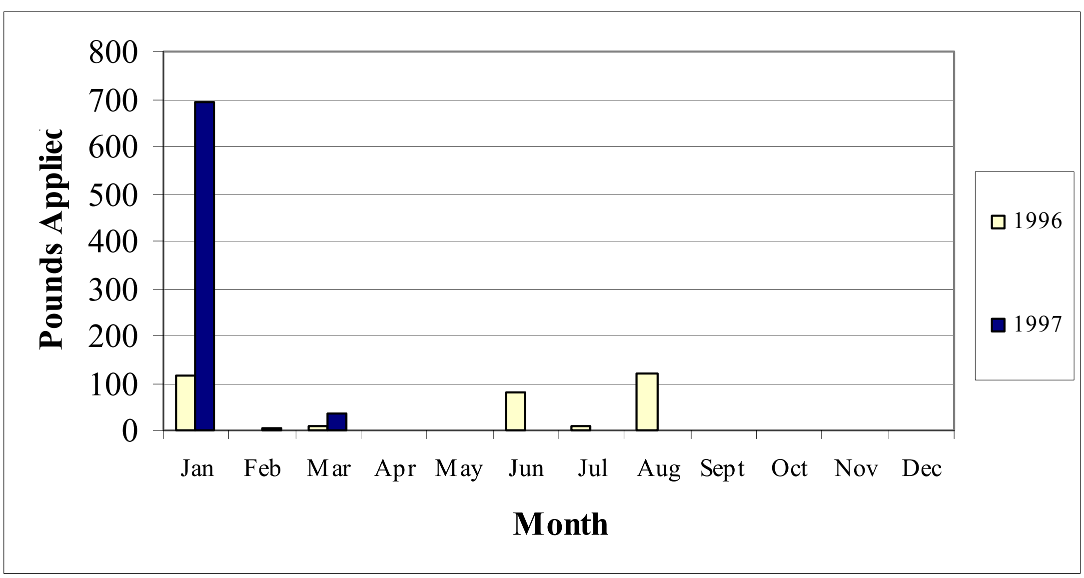
Figure 4. Pounds of Methidathion Applied in Tulare County, 1991 [a]



[a] Pounds applied by all methods to all crops in Tulare County (DPR 2004; queried June 27, 2003).

In contrast to Tulare County, in Sacramento County during air monitoring done in 1996 – 1997 very little methidathion was used, 332 pounds in 1996 and 733 pounds in 1997. In 1996, use occurred in January, June and July; in 1997 nearly all use occurred in January (Figure 5; note scale on y-axis). This use coincided with the two samples collected in January by Majewski and Baston (2002), in which methidathion was detected. Examination of use in 1998 – 2002 (data not shown) suggests that methidathion use in Sacramento County has remained low; in fact, no use was reported in 2000 through 2002. Based on the use data and limited detection of methidathion, data from Sacramento County were not used to estimate ambient air exposure.

Figure 5. Pounds of Methidathion Applied in Sacramento County, 1996 and 1997 [a]



[a] Pounds applied by all methods to all crops in Sacramento County (DPR 2004; queried June 27, 2003).

Table 11 summarizes ambient air and bystander exposure estimates to methidathion, based on monitoring done in Tulare County (Royce *et al.*, 1993a). Following WHS practice, acute ADD were calculated with 95% tolerance limits estimated using lognormal methods. DPR's experience with many large environmental datasets has shown that they are usually well described by the lognormal distribution. The 95% tolerance limit is the concentration that, with given probability, will be exceeded in 5% of future samples (Hahn and Meeker, 1991). It is calculated using lognormal distribution methods:

95% tolerance limit = exp{arithmetic mean of log concentrations + $g_{(.90;.95;\,n)}$*(sd of logs)}.

The multiplier g for 90% probability is provided by Hahn and Meeker (1991).

Table 11. Ambient Air and Bystander Exposure Estimates for Persons Exposed to Methidathion [a]

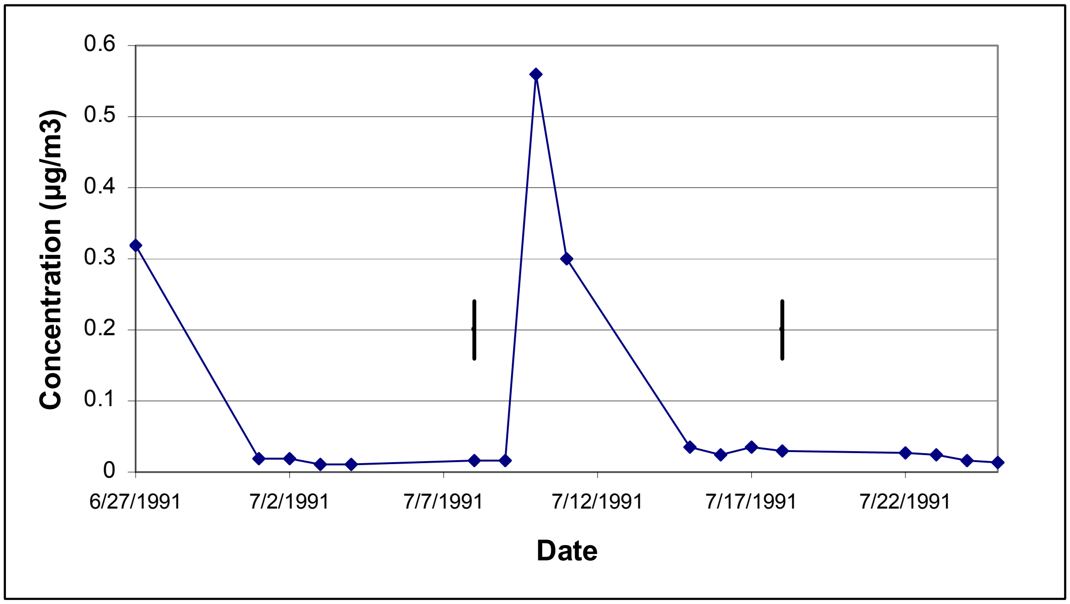
Site	Air concentration [b] (µg/m³) Mean	SD	95th % upper bound [c]	Acute ADD [d] (µg/kg/day) Infants	Adults	Seasonal ADD [e] (µg/kg/day) Infants	Adults	Annual ADD [f] (µg/kg/day) Infants	Adults
Ambient Air									
Site J [g]	0.079	0.159	0.660 [h]	0.389	0.185	0.047	0.022	0.035	0.017
Bystander									
North Station [g]	0.88	- -	- -	0.519	0.264	NA [i]	NA	NA	NA

[a] Data from monitoring done in Tulare County in 1991 (Royce *et al*., 1993a).
[b] Arithmetic mean and standard deviation (SD). Calculated using ½ limit of detection (LOD) for samples < LOD.
[c] Value (in µg/m³) used for acute exposure estimates. Calculated using lognormal distribution methods (see text).
[d] Acute Absorbed Daily Dosage (µg/kg/day) = (95th % upper bound air concentration) x (inhalation rate).
Calculation assumptions include:
- Infant inhalation rate = 0.59 m³/kg/day (Layton, 1993; US EPA, 1997)
- Adult inhalation rate = 0.28 m³/kg/day (Wiley *et al*., 1991; US EPA, 1997; OEHHA, 2000)
- Inhalation absorption is assumed to be 100%

[e] Seasonal ADD = (mean air concentration) x (inhalation rate). Calculation assumptions as above. Estimated season for SADD is 9 months.
[f] Annual ADD = (Seasonal ADD) x (annual use months per year)/12. Annual use estimated at 9 months.
[g] Site J = Jefferson Elementary School in Lindsay. This was the site with most samples above the LOD (see Table 4). North station was the application air monitoring site with the highest mean methidathion concentration in the 24 hours during and post-application; time-weighted average is used as the mean (see Table 5).
[h] Calculated from two weeks monitoring in which most samples were above the LOD (7/8/91-7/18/91).
[i] NA: Not applicable. Seasonal and annual exposure not anticipated for bystanders (see text).

Acute ADD for ambient air exposure was calculated using the 95% tolerance limit as explained above, based on air monitoring data from Site J in Tulare County during the two weeks in which most samples were above the LOD (see Figure 6; vertical bars show ranged of dates used). Acute ADD was estimated to be 0.389 µg/kg/day for infants and 0.185 µg/kg/day for adults (Table 11). These estimates are similar to exposure estimates recently published by Lee *et al.* (2002). Based on air monitoring data from Royce *et al.* (1993a), Lee *et al.* (2002) used a probabilistic analysis to estimate exposures to adults and children in Tulare County. Acute exposure estimates for children ranged 0.2 – 0.4 µg/kg/day (Table 5 in Lee *et al*., 2002), and for adults, 0.14 – 0.2 µg/kg/day (Table 6 in Lee *et al*., 2002).

Figure 6. Concentration of Methidathion in Ambient Air Monitoring in Tulare County, 1991 [a]



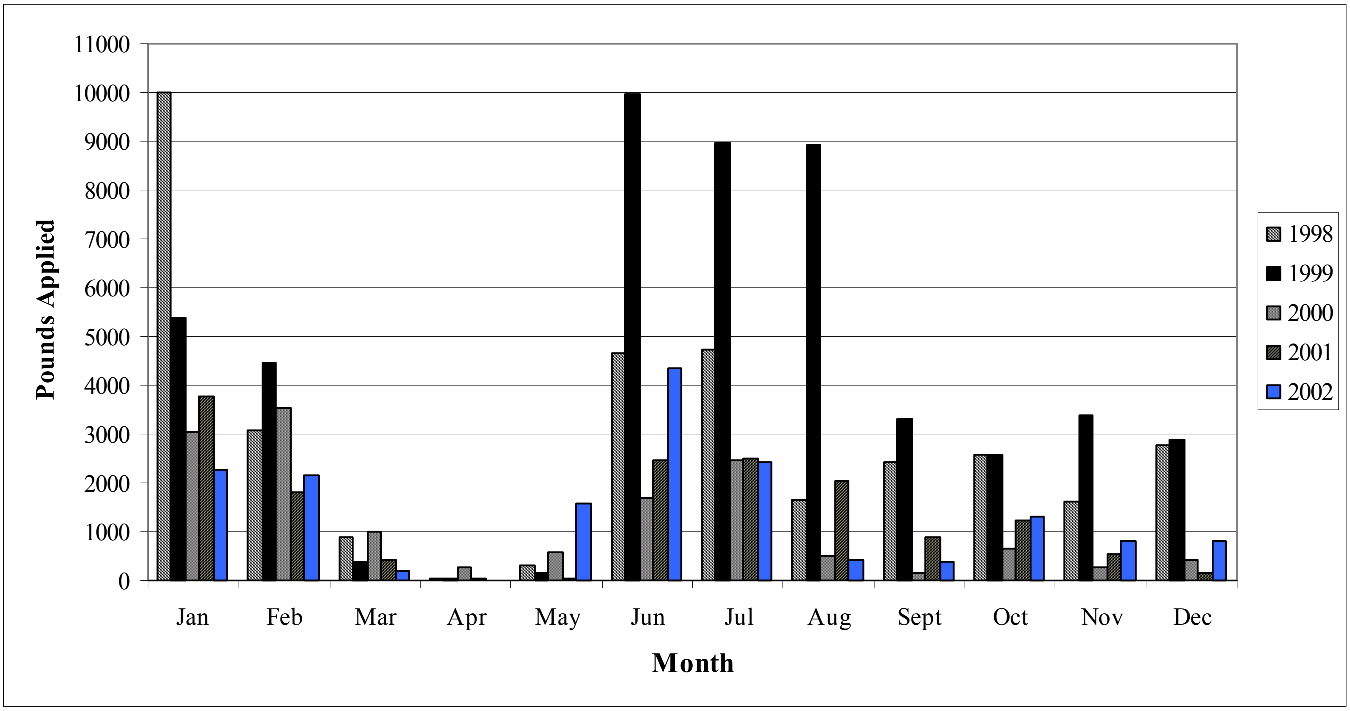
[a] Modified from Royce et al. (1993a). Results not corrected for background. Limit of detection was 0.01 µg/m^3. Vertical bars at 7/8/91 and 7/18/91 bracket span of data used for acute ADD exposure estimates.

Ambient air monitoring was done in 1991, during a time when high methidathion use was anticipated in Tulare County (Royce *et al.*, 1993a). Figure 4 confirms that use was high during the ambient air monitoring period: a total of 30,000 lbs was applied in June and 10,000 lbs in July. Nevertheless, the highest use interval was not captured, as monitoring was not begun until the end of June. Examination of daily methidathion use in Tulare County for 1991 (data not shown) reveals that the highest daily use (2,374 lbs) occurred on June 21; during ambient air monitoring daily use varied between 27 lbs and 1,401 lbs. On July 10, the date of the highest recorded ambient air concentration (see Figure 6), a total of 399 lbs was used in Tulare County; on the preceding two days, 202 lbs and 612 lbs were used (DPR, 2004; queried April 27, 2004).

To estimate annual and lifetime ambient air exposures to methidathion, temporal patterns were investigated by plotting pounds applied per month for each of the past five years for which data are available. Figure 7 displays monthly use patterns in Tulare County for 1998 – 2002 (DPR, 2004; queried April 23, 2004). Figure 7 shows that even in recent years (1998 and 1999), monthly use was as high as 10,000 lbs.

Figure 7 also shows that use in the most recent three years for which data are available (2000 – 2002) monthly use was never above 5,000 lbs. However, examination of daily use in 2002 reveals that daily use in June was as high as 896 lbs; this is greater than daily use seen in mid-July 1991, when the highest methidathion concentrations occurred during ambient air monitoring. Depending on how use is distributed throughout the county, ambient air exposure in some parts of Tulare County might potentially be as high in 2002 as in 1991; insufficient data are available to support lower exposure estimates. Inspection of Figure 7 shows that substantial use (> 500 lbs) occurred in seven to ten months each year. As previously explained in the Pesticide Application and Use section, methidathion use has been decreasing in California for several reasons, but there is no mechanism to prevent use from increasing again later. For this reason, annual exposure estimates rely on use patterns shown in Figure 7. Averaging monthly use across five years (data not shown) results in an estimated high-use period ($\geq$ %5 of annual use) of nine months (June – February).

Figure 7. Monthly Use of Methidathion in Tulare County, 1998-2002 [a]



[a] Pounds applied by all methods to all crops in Tulare County (DPR 2004; queried April 27, 2004).

Seasonal and annual exposure estimates reported in Table 11 were based on 9 high-use months. Seasonal ADD was estimated to be 0.047 μg/kg/day for infants and 0.022 μg/kg/day for adults. Annual ADD was estimated to be 0.035 μg/kg/day for infants and 0.017 μg/kg/day for adults.

Lee *et al.* (2002) estimated subchronic (> 14 days) and chronic (> 1 year) exposures for children and adults. For children, subchronic exposure estimates ranged 0.018 – 0.18 μg/kg/day and chronic exposure estimates ranged 0.002 – 0.012 μg/kg/day. For adults, subchronic exposure estimates ranged 0.01 – 0.1 μg/kg/day and chronic exposure estimates ranged 0.0012 – 0.006 μg/kg/day (Lee *et al*., 2002). Seasonal exposure estimates in Table 11 are in the range of the probabilistic estimates reported by Lee *et al*. (2002). The annual ADD estimates reported in Table 11 are higher, as they are based on assumed constant inhalation rates and ambient air concentrations for 9 months, while the probabilistic estimates reported by Lee *et al*. (2002) assumed a gamma distribution for inhalation rates and a lognormal distribution for air concentrations. Overall, there was little difference between exposure estimates reported in Table 11 and in Lee *et al*. (2002).

Bystanders at Application Sites

To estimate bystander exposure to methidathion in air, data were used from application site monitoring in the 1991 study in Tulare County (Royce *et al*., 1993a). Table 5 summarizes air concentrations during several monitoring periods at each of these stations. Table 11 summarizes the bystander exposure estimates. The 24-hour TWA for the north monitoring station (TWA = 0.88 μg/m^3) was used to estimate exposure. Acute ADD for bystanders was 0.519 μg/kg/day for infants and 0.246 μg/kg/day for adults. Seasonal or annual exposure to application site airborne methidathion levels is not expected because airborne concentrations are anticipated to reach ambient levels within a few days after the application, and seasonal and ambient air methidathion exposure estimates are given in Table 11.

EXPOSURE APPRAISAL

Handlers

Use of Surrogate Data

PHED data were used to estimate handler exposures for the various application methods. PHED, though useful, has limitations that prevent the use of distributional statistics on exposure estimates. PHED incorporates exposure data from many studies, each with a different minimum detection level for the analytical method used to detect residues in the sampling media. Moreover, as the detection of dermal exposure to the body regions was not standardized, some studies observed exposure to only selected body parts. Consequently, the subsets derived from the database for dermal exposure may have different numbers of observations (n) for each body part, which complicates interpretation of values taken from PHED. As no acceptable, chemical-specific, worker exposure monitoring data were available, use of PHED data provided the best exposure estimates possible. U.S. EPA also relied exclusively on PHED data for handler exposure estimates (Travaglini, 1999; U.S. EPA, 2001).

WHS believes upper-bound estimates are appropriate for short-term exposures because high-end exposures are possible, and WHS has an obligation to protect all individuals exposed during and after legal uses of methidathion (not just uses under "average" conditions). For short-term exposure estimates, it is irrelevant whether the upper bound is many times the size of the mean; the upper bound is used because data suggest that such exposures can happen.

Upper confidence limits are used for seasonal and chronic estimates based on PHED. For these exposures, upper confidence limits are used not because WHS believes that exposures are consistently greater than the population mean, but because available data are so sparse that it is likely that the sample mean is not close to the true population mean. In exposure monitoring, ranges of sample results can be quite broad, and can include values that are substantially higher than sample means (Grover *et al.*, 1986; Vercruysse *et al.*, 1999). Some studies have reported sample ranges that span as much as three orders of magnitude (e.g., Hines *et al.*, 2001). Thus, it is apparent that handlers could have exposures well above sample means; such estimates are not unreasonable. PHED data in particular pose difficulties because they are poorly characterized for the user, confounding assessment of the match between any given subset and the exposure scenario it is intended to represent. Upper confidence limits are used by DPR to address concerns specific to PHED (Powell, 2002).

Data quality grades in PHED have been assigned based on Quality Assurance/Quality Control data provided in exposure study reports. Grades A and B are high-quality grades, with lab recoveries of 90-110% and 80-100%, respectively (field recoveries range 70-120% and 50-120%); grade C represents moderate quality, with lab and field recoveries of 70-120% and 30-120%, respectively; E is the lowest quality grade, and is assigned to PHED data that do not meet basic quality assurance (U.S. EPA, 1998). Data quality grades for each PHED data set used in exposure estimates are summarized in the first table of each appendix.

Dermal data quality was generally high in the data sets used to generate exposure estimates, with the exception of those used to estimate exposure to M/L/A using backpack sprayers or low-pressure handwands, in which data quality was moderate. Inhalation data quality was high or moderate, with the exception of the data set used to estimate aerial applicator exposure, in which six of the 16 observations were of low data quality.

The appendices also summarize numbers of observations contained in each PHED subset. Subsets for M/L/A using low-pressure hand wand or backpack sprayer had 9-11 observations for each body part. This is a very small number of observations, increasing the uncertainty in estimates generated from these subsets. Other subsets which are rather small include M/L handling WP in WSP (6 – 15 observations) and aerial applicator (9 – 17 observations).

PUR data were used to estimate likely numbers of days workers were exposed, based on the distribution of applications in high-use California counties. These high-use periods describe a recent work history of the handler population, and they probably overestimate the workdays for any single individual. They provide the best available data for long-term exposure estimates, however.

DPR and U.S. EPA Estimates

Handler exposure estimates described in this EAD were generally higher than estimates from U.S. EPA (Travaglini, 1999). Differences in estimates by U.S. EPA (Travaglini, 1999) and DPR (present document) might be anticipated because U.S. EPA used geometric means to summarize PHED data, whereas DPR used arithmetic means, in accordance with the usual practice of DPR. Also, U.S. EPA estimates were based on means rather than the upper confidence limits used by DPR. However, DPR estimated internal dosages, and assumed a dermal absorption of 50%. U.S. EPA estimated potential exposures, as their Margins of Exposure (MOEs; values calculated for risk assessment purposes) for handlers relied on a dermal study (Travaglini, 1999). Differences in dermal absorption assumptions tended to partially mitigate the differences occurring in PHED values used by U.S. EPA and DPR. Finally, U.S. EPA exposure estimates covered a range of PPE and engineering combinations, and DPR estimates addressed only the combinations required by California and federal law.

Selection of Scenarios

As stated above in the Significant Exposure Scenarios section, scenarios used in this assessment were based on product labels current as of April 2004. U.S. EPA (2001) described several changes in uses and required PPE and engineering controls that are anticipated based on their occupational risk assessment. As those changes are pending as of preparation of this EAD, however, they were not considered here. As described by U.S. EPA (2001), any changes required in response to their occupational risk assessment will decrease estimated exposure for affected scenarios.

Fieldworkers

Acceptable monitoring data were lacking for fieldworker exposures, as for handlers. Exposure estimates for fieldworkers were based on chemical-specific, but not necessarily crop-specific, DFR values. Residues may dissipate at different rates on different crops, due to factors such as leaf topography and physical and chemical properties of leaf surfaces.

Extent of foliage contact, unlike DFR, is not chemical specific, and transfer factor values for various crop activities are readily available, based on studies using other chemicals. Where crop-specific TF were not available, general defaults were used. These defaults were likely to be conservative (U.S. EPA, 2000).

However, information is lacking about exposures resulting from some activities, such as weeding and roguing (removal of diseased crop plants) in cotton, and how these exposures might compare with those of scouts.

As with handlers, seasonal exposure estimates for fieldworkers were partly based on PUR data, in that months in which pesticide use overlapped fieldworker activities were considered to be months in which fieldworkers were potentially exposed to pesticides. This is a conservative estimate, which may result in an overestimate of seasonal, annual and lifetime exposures.

Ambient Air and Bystander Exposure Estimates

Public exposures to airborne methidathion were estimated based on concentrations of methidathion in air and assumptions about uptake of methidathion from the air. No biomonitoring or other exposure monitoring data were available. Exposure estimates were provided for adults for consistency with other scenarios, and for infants as likely worst-case estimates because infants have the greatest inhalation rate per body weight.

Ambient air exposure estimates were based on one site in Tulare County, and there is insufficient information available to determine how representative this site is. At this site, as at other monitored sites, there were a number of samples in which methidathion was not detected. Although ambient air monitoring sites were selected based on anticipated nearby methidathion use, applications of methidathion were not confirmed. It is possible that no applications occurred near the sites where methidathion was not detected, or that the analytical method was not sufficiently sensitive to detect ambient methidathion concentrations. Additionally, each site was monitored only 4 days per week for a relatively short (8-week) period. Fridays through Sundays were not monitored. It is unknown whether days of the week differ systematically in use or ambient air concentrations of methidathion. However, ambient air monitoring occurred during a relatively high-use time (though the highest use was apparently not captured). Use during much of the year is lower than it was in June and July of 1991, particularly in recent years. This suggests that seasonal and annual ambient air exposure estimates based on monitoring done in 1991 are more likely to have been overestimated than underestimated.

For bystander exposure estimates, data from the north monitoring station, 25 m from the application site, were used as a reasonable worst-case estimate for methidathion concentration in air for acute exposure estimates. For this reason, the mean methidathion concentration at this site was used rather than the 95th-percentile upper bound estimate.

Seasonal or annual exposure to application site airborne methidathion levels is not expected because airborne concentrations are anticipated to reach ambient levels within a few days after the application. Applications of methidathion to citrus are allowed a maximum of twice per year. As shown in the monitoring data reported by Royce *et al*. (1993), methidathion concentrations in air decrease soon after application, and high concentrations are probably not relevant for more than one to a few days. Airborne concentrations of active ingredients also decrease as distance from the application site decreases (MacCollom *et al.*, 1968; Seibers *et al.*, 2003), and it is unlikely that a person would be repeatedly exposed to elevated airborne concentrations.

REFERENCES

Andrews, C. 2000. Worker Health and Safety Branch Policy on the Statistical Analysis for Dislodgeable Foliar Residue Data. Memo No. HSM-00011. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation.

Aprea, C., Sciarra, G., Sartorelli, P., Desideri, E., Amati, R. and Sartorelli, E. 1994. Biological monitoring of exposure to organophosphorus insecticides by assay of urinary alkylphosphates: influence of protective measures during manual operations with treated plants. *Int. Arch. Occup. Environ. Health* 66:333-338.

Baker, L.W., Fitzell, D.L., Seiber, J.N., Parker, T.R., Shibamoto, T., Poore, M.W., Longley, K.E., Tomlin, R.P., Propper, R. and Duncan, D.W. 1996. Ambient air concentrations of pesticides in California. *Environ. Sci. Technol*. 30:1365–1368.

Carmen, G.E., Iwata, Y., Dusch, M.E., Dinoff, T.M. and Gunther, F.A. 1981. Residues of malathion and methidathion on and in fruit after dilute and low-volume spraying. *Bull. Environ. Contam. Toxicol.* 27:864-868.

Cassidy, J.E., Wood, N.F. and Lasker, K. 1969. Desmethyl GS-13005 and Other Metabolites in the Urine of Rats Fed GS-13005-5-carbonyl-^{14}C. Unpublished study submitted by Ciba-Geigy Corporation. Report No. GAAC-69037-A. DPR Volume 298-120.

CAST. 2002. Urban and Agricultural Communities: Opportunities for Common Ground. Task Force Report No. 138. Ames, IA: Council for Agricultural Science and Technology. http://www.cast-science.org/pubs/urbanagricultural.pdf

Chaisson, C.F., Sielken, R.L., Jr, and Waylett, D.K. 1999. Overestimation bias and other pitfalls associated with the estimated 99.9th percentile in acute dietary exposure assessments. *Reg. Tox. Pharm.* 29: 102-127.

Chopade, H.M. and Dauterman, W.C. 1981. Studies on the *in vitro* metabolism of methidathion by rat and mouse liver. *Pestic. Biochem. Physiol.* 15:105-119.

Dawson, J.L. 2003. Human Health Risk Assessment: Carbaryl. Washington, DC: Health Effects Division, Office of Pesticide Programs, U.S. Environmental Protection Agency.

De Vos, N.E. 1992. Artichoke production in California. *HortTechnology* 2:438-444.

Donahue, J. 1996. Revised policy on dermal absorption default for pesticides. Memo No. HSM-96005. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency.

Dong, M.H. 1990. Memorandum: Dermal transfer factor for cotton scouts. Memo No. HSM-90001. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation.

Dong, M.H., Krieger, R.I., and Ross, J.H. 1992. Calculated reentry interval for table grape harvesters working in California vineyards treated with methomyl. *Bull. Environ. Contam. Toxicol.* 49:708-714.

DPR. 2000a. Pesticide Use Report, Annual 1998 Indexed by Chemical. Sacramento, CA: Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/pur/pur98rep/chmrpt98.pdf

DPR. 2000b. Pesticide Use Report, Annual 1999 Indexed by Chemical. Sacramento, CA: Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/pur/pur99rep/chmrpt99.pdf

DPR. 2001. Pesticide Use Report, Annual 2000 Indexed by Chemical. Sacramento, CA: Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/pur/pur00rep/chmrpt00.pdf

DPR. 2002. Pesticide Use Report, Annual 2001 Indexed by Chemical. Sacramento, CA: Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/pur/pur01rep/comrpt01.pdf

DPR. 2003. Pesticide Use Report, Annual 2002 Indexed by Chemical. Sacramento, CA: Department of Pesticide Regulation. Available at: http://www.cdpr.ca.gov/docs/pur/pur02rep/comrpt02.pdf

DPR. 2004. California Pesticide Information Portal (CalPIP), Pesticide Use Report database. Website accessed for database queries on several dates in 2003 and 2004. http://calpip.cdpr.ca.gov/cfdocs/calpip/prod/main.cfm

Drevenkar, V., Radic, Z., Vasilic, Z. and Reiner, E. 1991. Dialkylphosphorus metabolites in the urine and activities of esterase in the serum as biochemical indices for human absorption of organophosphorus pesticides. *Arch. Environ. Contam. Toxicol.* 20:417-422.

Durham, W. and Wolfe, H. 1962. Measurement of the exposure of workers to pesticides. *Bull. World Health Org*. 26:75-91.

Edmiston, S., Cowan, C. and Welsh, A. 1999. California Farm Worker Activity Profile: A Database of Farm Worker Activity Demographics. Report No. HS-1751. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/whs/pdf/hs1751.pdf

Epstein, L. and Bassein, S. 2003. Patterns of pesticide use in California and the implications for strategies for reduction of pesticides. *Annual Review of Phytopathology* 41:351-375.

Grover, R., Cessna, A.J., Muir, N.I., Riedel, D., Franklin, C.A. and Yoshida, K. 1986. Factors affecting the exposure of ground-rig applicators to 2,4-D dimethylamine salt. *Arch. Environ. Contam. Toxicol.* 15:677-686.

Hahn, G.J. and Meeker, W.Q. 1991. Statistical Intervals: A Guide for Practitioners. New York, John Wiley & Sons, Inc.

Hensley, J.R. 1981a. Supracide worker exposure and dislodgeable residue studies in alfalfa. Unpublished study submitted by Ciba-Geigy Corporation, Greensboro, NC. Report No. EIR-81011. DPR Volume Number 298-107.

Hensley, J.R. 1981b. Supracide worker exposure and dislodgeable residue studies in citrus. Unpublished study submitted by Ciba-Geigy Corporation, Greensboro, NC. Report No. EIR-81013. DPR Volume Number 298-107.

Hensley, J.R. 1981c. Supracide worker exposure and dislodgeable residue studies in cotton. Unpublished study submitted by Ciba-Geigy Corporation, Greensboro, NC. Report No. EIR-80002. DPR Volume Number 298-003.

Hernandez, B.Z., Spencer, J., Schneider, F., Welsh, A. and Fredrickson, S. 1998. A Survey of Dislodgeable Pesticide Residues on Crop Foliage at Field Reentry, 1994-1995. Report No. HS-1728. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/whs/pdf/hs1728.pdf

Hines, C.J., Deddens, J.A., Tucker, S.P. and Hornung, R.W. 2001. Distributions and determinants of pre-emergent herbicide exposures among custom applicators. *Ann. Occup. Hyg.* 45:227-239.

Iwata, Y., Knaak, J.B., Spear, R.C. and Foster, R. J. 1977. Worker reentry into pesticide-treated crops. I. Procedure for the determination of dislodgeable pesticide residues on foliage. *Bull. Environ. Contam. Toxicol.* 18:649-655.

Iwata, Y., Carman, G.E. and Gunther, F.A. 1979. Worker environment research: methidathion applied to orange trees. *J. Agric. Food Chem.* 27:119-129.

Krieger, R.I., Dinoff, T.M., Korpalski, S. and Peterson, J. 1998. Protectiveness of Kleengard® LP and Tyvek®-Saranex 23-P during mixing/loading and airblast application. *Bull. Environ. Contam. Toxicol.* 61:455-461.

Kuvila, K.M. and Foe, C.G. 1995. Concentrations, transport and biological effects of dormant spray pesticides in the San Francisco estuary, California. *Environ. Toxicol Chem*. 14:1141-1150.

Lail, L.J. 1991. Technical Methidathion Product Chemistry: Data Requirements. Unpublished study submitted by Ciba-Geigy Corporation, Greensboro, NC. Study No. PC-91-001. DPR Volume Number 298-156.

Landgren, C.G. 1996. Calibrating and Using Backpack Sprayers. Corvallis, OR: Pacific Northwest Extension Publication No. PNW 320.

Lee, S., McLaughlin, R., Harnly, M., Gunier, R. and Kreuzer, R. 2002. Community exposure to airborne agricultural pesticides in California: ranking of inhalation risks. Environmental Health Perspectives 110:1175-1184.

Lewis, C.M. 2001. Methidathion: Dietary and drinking water risk assessment. Sacramento, CA: Medical Toxicology Branch, Department of Pesticide Regulation.

Maddy, K.T. 1975. Summary of a Worker Reentry Safety Study of Phosalone (Zolone®) on Citrus - Sept.-Oct.1974. Report published by California Agricultural Chemicals and Food, Report No. ACF 59-052. Available as Report No. HS-52 from Worker Health and Safety Branch, Department of Pesticide Regulation, Sacramento, CA. http://www.cdpr.ca.gov/docs/whs/pdf/hs52.pdf

Maddy, K.T. 1976. A Study of Foliar Residues Following Application of Supracide to Orange Trees: Riverside County Jun 1975, Kern County July 1975. Report published by California Agricultural Chemicals and Food, Report No. ACF 59-172. Available as Report No. HS-172 from Worker Health and Safety Branch, Department of Pesticide Regulation, Sacramento, CA. http://www.cdpr.ca.gov/docs/whs/pdf/hs172.pdf

Maddy, K.T., Gibbons, D., Richmond, D.M. and Fredrickson, S.A. 1983. Potential Exposure of Loader/Applicators to Methidathion (Supracide) During Applications to Citrus in Riverside County, California in 1982. Report published by California Department of Food and Agriculture. Available as Report No. HS-1062 from Worker Health and Safety Branch, Department of Pesticide Regulation, Sacramento, CA. http://www.cdpr.ca.gov/docs/whs/pdf/hs1062.pdf

Maddy, K.T., Au, C.M. and Cooper, C. 1984a. A Degradation Study of Dislodgeable Methidathion Residue on Orange Foliage in Tulare County, California During May - June 1983. Report published by California Department of Food and Agriculture. Available as Report No. HS-1149 from Worker Health and Safety Branch, Department of Pesticide Regulation, Sacramento, CA. http://www.cdpr.ca.gov/docs/whs/pdf/hs1149.pdf

Maddy, K.T., Jacobs, K.C. and Cooper, C. 1984b. A Degradation Study of Dislodgeable Methidathion Residue on Orange Foliage in Fresno County. Report published by California Department of Food and Agriculture. Available as Report No. HS-1167 from Worker Health and Safety Branch, Department of Pesticide Regulation, Sacramento, CA. http://www.cdpr.ca.gov/docs/whs/pdf/hs1167.pdf

Majewski, M.S. and Baston, D.S. 2002. Atmospheric Transport of Pesticides in the Sacramento, California, Metropolitan Area, 1996 – 1997. Water Resources Investigations Report 02-4100, National Water Quality Assessment Program. Sacramento, CA: U.S. Geological Survey. Available at: http://www.cdpr.ca.gov/docs/sw/contracts/usgs024100.pdf.

Mehler, L. 2001. Summary Report of Cases Reported to the California Pesticide Illness Surveillance Program 1982-1999 with Health Effects Definitely, Probably, or Possibly Related to Exposure to Methidathion, Alone or In Combination. Internal report, DPR, Worker Health and Safety Branch.

Murphy, S.D. 1986. Toxic effects of pesticides. In: *Casarett and Doull's Toxicology: The Basic Science of Poisons*, 3rd Ed. MacMillan Publishing Co., New York. pp. 519-581.

NIOSH (National Institute for Occupational Safety and Health). 1987. Respirator Decision Logic. NIOSH, U.S. Department of Health and Human Services.

Newell, J. 1987. Density of Methidathion Technical. Unpublished study submitted by Ciba-Geigy Corporation, Greensboro, NC. Report Code FDTR-87-19. DPR Volume Number 298-104.

Nigg, H.N., Stamper, J.H. and Queen, R.M. 1984. The development and use of a universal model to predict tree crop harvester pesticide exposure. *Amer. J. Indust. Hyg*. 45:182-186.

O'Malley, M., Verder-Carlos, M.-L., Mehler, L. and Richmond, D. 1994, Risk Factors for Cholinesterase and Non-cholinesterase Effects of Exposure to Organophosphate Insecticides in California Agricultural Workers: 1982-1990. Report No. HS-1688. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/whs/pdf/hs1688.pdf

PHED. 1995. Pesticide Handlers Exposure Database, Version 1.1. Prepared for the PHED Task Force: Health Canada, U.S. EPA and the American Crop Protection Association, by Versar, Inc., Springfield, VA.

Polan, C.E. and Chandler, P.T. 1971. Metabolism of ^{14}C-carbonyl labeled Supracide by lactating cows. *J. Dairy Sci.* 54:847-853.

Popendorf, W.J., Spear, R.C., Leffingwell, J.T., Yager, J. and Kahn, E. 1979. Harvester exposure to Zolone® (phosalone) residues in peach orchards. *J. Occup. Med.* 21:189-194.

Popendorf, W.J. and Leffingwell, J.T. 1982. Regulating OP pesticide residues for farmworker protection. *Residue Rev.* 82:128-201.

Powell S., 2002. Approximating Confidence Limits for Upper Bound and Mean Exposure Estimates from the Pesticide Handlers Exposure Database (PHED V1.1). Memo No. HSM-02037, dated September 27. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation.

Rordorf, B.F. 1988. Report on Vapor Pressure Density of Methidathion Technical. Unpublished study submitted by Ciba-Geigy Corporation, Greensboro, NC. Report Code FDTR-87-19. DPR Volume Number 298-104.

Rosenheck, L. 1998a. Dissipation of Dislodgeable Foliar Residues of Methidathion Applied to Citrus. Unpublished study submitted by Novartis Crop Protection, Inc., Greensboro, NC, Project No. ABR-98014. DPR Volume Number 298-222.

Rosenheck, L. 1998b. Dissipation of Dislodgeable Foliar Residues of Methidathion Applied to Cotton. Unpublished study submitted by Novartis Crop Protection, Inc., Greensboro, NC, Project No. ABR-98086. DPR Volume Number 298-223.

Rosenheck, L. 1998c. Occupational Exposure Assessment for Methidathion. Unpublished study submitted by Novartis Crop Protection, Inc., Greensboro, NC, Project No. ABR-98020. DPR Volume Number 298-224.

Ross, L.J., Stein, R., Hsu, J., White, J. and Hefner, K. 1996. Distribution and mass loading of insecticides in the San Joaquin River, California: Winter 1991-92 and 1992-93. Environmental Monitoring and Pest Management Branch Report No. EH 96-02. Sacramento, CA: California Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/empm/pubs/ehapreps/eh9602.htm.

Royce, B.R., Longley, K.E. and Gump, B.H. 1993a. Airborne Concentrations of Methidathion and Methidaoxon in Central Tulare County from Sampling Conducted in June and July 1991. Fresno, CA: Report prepared by the Engineering Research Institute for the California Air Resources Board, Contract No. A032-094.

Royce, B.R., Longley, K.E. and Gump, B.H. 1993b. Overview of Sampling and Analysis Program: Report prepared by the Engineering Research Institute for the California Air Resources Board, Contract No. A032-094.

Simoneaux, B. and Marco, G.J. 1984. Dermal absorption of thiadiazole-14C-methidathion by mice. Unpublished study submitted by Ciba-Geigy Corporation, Greensboro, NC. Study No. ABR-86122. DPR Volume Number 298-107.

Szolics, I.M. 1987. Disposition of Methidathion in the Rat (General Metabolism). Unpublished study submitted by Ciba-Geigy Corporation. Laboratory Study No. ABR-86122. DPR Volume 298-128.

Teitelman, U., Alder, M. and Levy, I. 1975. Treatment of massive poisoning by the organophosphate pesticide methidathion. *Clin. Toxicol.* 8:277-282.

Thompson, N.P., Nigg, H.N. and Brooks, R.F. 1979. Dislodgeable Residue of Supracide on Citrus Leaves. *J. Agric. Food Chem.* 27:589-592.

Thongsinthusak, T., Brodberg, R.K., Ross, J.H., Gibbons, D. and Krieger, R.I. 1991. Reduction of pesticide exposure by using protective clothing and enclosed cabs. Report No. HS-1616. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation.

Thongsinthusak, T., Ross, J.H. and Meinders, D. 1993. Guidance for the preparation of human pesticide exposure assessment documents. Report No. HS-1612. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/whs/pdf/hs1612.pdf

Thongsinthusak, T., Ross, J.H. and Dong, M.H. 1999. Significance of dermal dose levels in dermal absorption studies of pesticides. Report No. HS-1801. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/whs/pdf/hs1801.pdf

Tomlin, C. 1994. The Pesticide Manual, 10th Edition**.** British Crop Protection Council, London. pp. 675-676.

Travaglini, R. 1999. Human health risk assessment (DRAFT): Methidathion. Washington, DC: Health Effects Division, Office of Pesticide Programs, United States Environmental Protection Agency, Washington, DC.

Tsatsakis, A.M., Aguridakis, P., Michalodimitrakis, M.N., Tsakalov, A.K., Alegakis, A.K., Koumantakis, E. and Troulakis, G. 1996. Experiences with acute organophosphate poisonings in Crete. *Vet. Human Toxicol.* 38:101-107.

Turner, B., Powell, S., Miller, N. and Melvin, J. 1989. A Field Study of Fog and Dry Deposition as Sources of Inadvertent Pesticide Residues on Row Crops. Environmental Monitoring and Pest Management Branch Report No. EH 89-11. Sacramento, CA: California Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/empm/pubs/ehapreps/eh8911.htm.

UC IPM. 2004. University of California Pest Management Guidelines. How to Manage Pests: Pests of Agriculture, Floriculture and Turf. Statewide Integrated Pest Management Program, University of California Department of Agriculture and Natural Resources. Website accessed for crop-specific information in April 2004. http://www.ipm.ucdavis.edu/PMG/crops-agriculture.html

U.S. EPA. 1996a. Health Effects Test Guidelines. OPPTS 870.7600: Dermal Penetration. Public Draft Document, EPA 712-C-96-350. Washington, DC: Office of Prevention, Pesticides and Toxic Substances, United States Environmental Protection Agency.

U.S. EPA. 1996b. Occupational and Residential Exposure Test Guidelines. OPPTS 875.2100: Foliar Dislodgeable Residue. 712-C-96-267. Washington, DC: Office of Prevention, Pesticides and Toxic Substances, United States Environmental Protection Agency.

U.S. EPA. 1997. Exposure factors handbook. EPA/600/P-95/002Fa. Washington, D.C.: Office of Research and Development, U.S. Environmental Protection Agency.

U.S. EPA. 1998. PHED Surrogate Exposure Guide. Estimates of Worker Exposure from the Pesticide Handler Exposure Database, Version 1.1. Washington, DC: Office of Prevention, Pesticides and Toxic Substances, United States Environmental Protection Agency.

U.S. EPA. 2000. Agricultural Transfer Coefficients. Policy No. 003.1 (dated August 7). Washington, DC: Science Advisory Council for Exposure, Health Effects Division, Office of Pesticide Programs.

U.S. EPA. 2001. Interim Reregistration Eligibility Decision for Methidathion. List A, Case 0034. Washington, DC: Office of Prevention, Pesticides and Toxic Substances, United States Environmental Protection Agency.

Vercruysse, F., Drieghe, S., Steurbaut, W. and Dejonckeere. 1999. Exposure assessment of professional pesticide users during treatment of potato fields. *Pest. Sci*. 55:467-473.

Versar. 1992. PHED: The Pesticide Handlers Exposure Database reference manual. Prepared for the PHED Task Force: Health and Welfare Canada, U. S. Environmental Protection Agency, National Agricultural Chemicals Association. Springfield, VA: Versar, Inc.

Wang, R., Schneider, F., Alcoser, D., Saiz, S., Cooper, C. and Bisbiglia, M. 1987. Pesticide Exposure to Applicators During Dormant Spraying of Trees While in an Enclosed Cab Equipped with a Charcoal Air Filtration System in California, January 1986. Report published by California Department of Food and Agriculture. Available as Report No. HS-1390 from Worker Health and Safety Branch, Department of Pesticide Regulation, Sacramento, CA. http://www.cdpr.ca.gov/docs/whs/pdf/hs1390.pdf

Ware, G.W., Morgan, D.P., Estesen, B.J., Cahill, W.P. and Whitacre, D.M. 1973. Establishment of reentry intervals for organophosphate-treated cotton fields based on human data: I. Ethyl- and methyl parathion. *Arch. Environ. Contam. Tox.* 1:48-59.

Ware, G.W., Morgan, D.P., Estesen, B.J. and Cahill, W.P. 1974. Establishment of reentry intervals for organophosphate-treated cotton fields based on human data: II. Azodrin, ethyl and methyl parathion. *Arch. Environ. Contam. Tox.* 2:117-129.

Ware, G.W., Morgan, D.P., Estesen, B.J. and Cahill, W.P. 1975. Establishment of reentry intervals for organophosphate-treated cotton fields based on human data: III. 12 to 72 hours post-treatment exposure to monocrotophos, ethyl- and methyl parathion. *Arch. Environ. Contam. Tox.* 3:289-306.

Zhang, M., Wilhoit, L. and Geiger, C. 2004. Dormant Season Organophosphate Use in California Almonds. Report No. PM04-01. Sacramento, CA: Pest Management and Licensing, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/pmap/pubs/pm0401.pdf

Zoppellari, R., Targa, L., Tonini, P. and Zatelli, R. 1990. Acute poisoning with methidathion: A case. *Human Exper. Toxicol.* 9:415-419.

Zweig, G., Adams, J.D. and Blondell, J. 1980. Minimizing occupational exposure to pesticides: Federal reentry standards for farm workers (present and proposed). *Residue Rev.* 75:103-110.

Zweig, G., Leffingwell, J.T. and Popendorf, W. 1985. The relationship between dermal pesticide exposure by fruit harvesters and dislodgeable foliar residues. *J. Environ. Sci. Health* B20:27-59.

APPENDICES

Appendix 1: Subset from PHED for Exposure of Mixer/Loaders of Wettable Powders.

Appendix 2: Subset from PHED for Exposure of Mixer/Loaders of Emulsifiable Concentrates.

Appendix 3: Subset from PHED for Exposure of Aerial Applicator.

Appendix 4: Subset from PHED for Exposure of Flagger.

Appendix 5: Subset from PHED for Exposure of Airblast Applicator.

Appendix 6: Subset from PHED for Exposure of Ground Boom Applicator.

Appendix 7: Subset from PHED for Exposure of Mixer/Loader/Applicator Using Backpack Sprayer.

Appendix 8: Subset from PHED for Exposure of Mixer/Loader/Applicator Using Low-Pressure Handwand.

Notes

Appendices 1 – 8 provide detailed information on values used in handler exposure estimates. As described in the Exposure Assessment section, the Pesticide Handlers Exposure Database (PHED) combines exposure data from multiple field monitoring studies of different AIs. The user selects a subset of the data having the same or a similar application method and formulation type as the target scenario. Sufficient information is given in the appendix for each scenario to allow other PHED users to duplicate the subsets and generate the same values.

Once the PHED subsets were generated, inputs for exposure calculations were entered, according to WHS policy. Exposures were requested in mg per pound of AI handled, because the total work time spent within each handling task is not as well defined. For dermal exposure, both actual and estimated head patches were included. For inhalation exposure, the WHS default inhalation rate for handlers of 16.7 L/min was used. Clothing and gloves were chosen based on requirements listed on the label.

Due to an error in PHED (U.S. EPA, 1998), values for exposure to feet are incorrectly reported, and often omitted entirely. When no exposure was reported for feet, dermal totals were corrected by addition of the best estimate of feet exposure, calculated by multiplying the value for lower legs by 0.52 (ratio of feet/lower leg surface area; U.S. EPA, 1997). In Appendix 3, a value was reported for feet exposure by PHED; this value was replaced by the estimate based on exposure reported for lower legs.

Appendix 1: M/L, Water Soluble Bags Containing Wettable Powder

Table 1-1. Description of PHED subsets [a]

Parameter	Specifications used to generate subsets	Actual characteristics of resulting subsets
Data Quality Grades [b]	A,B	A,B
Solid Type	Wettable powder	Wettable Powder
Package Type	Water Soluble Bag	Water Soluble Bag

[a] Subsets of Mixer/Loader data in the Pesticide Handlers Exposure Database (PHED). Parameter descriptions are from screens displayed in the PHED program.
[b] Data quality grades are defined in the text and in Versar (1992).

Figure 1-1. Summary of results from the Pesticide Handlers Exposure Database (PHED) dermal subset, copied from the results screen displayed after inputs for exposure calculations have been entered [a]

SUMMARY STATISTICS FOR CALCULATED DERMAL EXPOSURES

SCENARIO: Long pants, long sleeves, gloves

Subset Name: S3DERMAL.MLOD

PATCH LOCATION	MICROGRAMS PER LB AI MIXED Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	3.51	165.0541	1.1942	15
NECK.FRONT	.423	155.9811	.1734	15
NECK.BACK	.2933	167.61	.0978	15
UPPER ARMS	2.619	17.2127	2.5837	6
CHEST	1.8046	83.2317	1.1207	12
BACK	1.8046	83.2317	1.1207	12
FOREARMS	1.089	17.2176	1.0743	6
THIGHS	4.9023	204.1674	1.6636	12
LOWER LEGS	1.19	86.1261	.7092	12

[a] Subset criteria included actual and estimated head patches. Of the 15 head observations, all were actual.

Table 1-2. PHED data from dermal, hand, and inhalation subsets [a]

Exposure Category	Exposure (μg/lb AI handled) [a]	Replicates in subset [b]	Short-Term Multiplier [c]	Long-Term Multiplier [c]
Dermal (non-hand) [d]	18.255	12	5	2
Hand (with gloves)	0.056	6	9	2
Inhalation	0.277	12	5	2

[a] Results from subsets of Mixer/Loader data in the Pesticide Handlers Exposure Database (PHED).
[b] Median number of replicates was used for Dermal (non-hand).
[c] Multipliers are explained in the Exposure Assessment section and in Powell (2002).
[d] Dermal total includes addition of default feet value of 0.52 x (value for lower legs); ratio of feet/lower leg surface area (U.S. EPA, 1997).

Table 1-3. Values Used in Short-Term and Long-Term Exposure Calculations [a]

	Short-Term		Long-Term	
Total Dermal	5(18.3) + 9(0.56) =	91.8 μg/lb AI handled	2(18.3) + 2(0.56) =	36.6 μg/lb AI handled
Inhalation [b]	5(0.0277) =	0.138 μg/lb AI handled	2(0.0277) =	0.055 μg/lb AI handled

[a] Values from Table 1-2.
[b] Inhalation data multiplied by 0.1 for use of respirator (NIOSH, 1987).

Appendix 2: M/L, Closed System, Liquids

Table 2-1. Description of PHED subsets [a]

Parameter	Specifications used to generate subsets	Actual characteristics of resulting subsets
Data Quality Grades [b]	A,B	A,B
Liquid Type	Emulsifiable concentrate, aqueous suspension, microencapsulated, solution, or undiluted liquid	All emulsifiable concentrate
Mixing Procedure	Closed, mechanical pump or gravity feed	Closed

[a] Subsets of Mixer/Loader data in the Pesticide Handlers Exposure Database (PHED). Parameter descriptions are from screens displayed in the PHED program.
[b] Data quality grades are defined in the text and in Versar (1992).

Figure 2-1. Summary of results from the Pesticide Handlers Exposure Database (PHED) dermal subset [a]

SUMMARY STATISTICS FOR CALCULATED DERMAL EXPOSURES
SCENARIO: Long pants, long sleeves, gloves

PATCH LOCATION	MICROGRAMS PER LB AI MIXED Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	1.6959	121.3279	.9508	22
NECK.FRONT	1.5225	278.5222	.2418	22
NECK.BACK	.456	280.8991	.0729	22
UPPER ARMS	1.3441	96.6967	.7988	21
CHEST	1.8416	93.4405	1.0577	16
BACK	1.8416	93.4405	1.0577	16
FOREARMS	.5474	98.5203	.3206	21
THIGHS	2.3398	81.9301	1.5773	16
LOWER LEGS	1.292	85.7276	.8778	21

Subset Name:
S6DERMAL.MLOD

[a] Subset criteria included actual and estimated head patches. Of the 22 head observations, all were actual.

Table 2-2. PHED data from dermal, hand, and inhalation subsets [a]

Exposure Category	Exposure (µg/lb AI handled) [a]	Replicates in subset [b]	Short-Term Multiplier [c]	Long-Term Multiplier [c]
Dermal (non-hand) [d]	13.55	21	4	1
Hand (with gloves)	5.72	31	4	1
Inhalation	0.128	27	4	1

[a] Results from subsets of Mixer/Loader data in the Pesticide Handlers Exposure Database (PHED).
[b] Median number of replicates was used for Dermal (non-hand).
[c] Multipliers are explained in the Exposure Assessment section and in Powell (2002).
[d] Dermal total includes addition of default feet value of 0.52 x (value for lower legs); ratio of feet/lower leg surface area (U.S. EPA, 1997).

Table 2-3. Values Used in Short-Term and Long-Term Exposure Calculations [a]

	Short-Term		Long-Term	
Total Dermal	4(13.55) + 4(5.72) =	77.1 µg/lb AI handled	1(13.55) + 1(5.71) =	19.3 µg/lb AI handled
Inhalation [b]	4(0.0128) =	0.051 µg/lb AI handled	1(0.0128) =	0.013 µg/lb AI handled

[a] Values from Table 2-2.
[b] Inhalation data multiplied by 0.1 for use of respirator (NIOSH, 1987).

Appendix 3: Aerial Applicator, Liquids, Open Cockpit

Table 3-1. Description of PHED subsets [a]

Parameter	Specifications used to generate subsets	Actual characteristics of resulting subsets
Data Quality Grades [b]	A,B,C	A,B,C
Liquid Type	Not specified	All emulsifiable concentrate
Solid Type	Exclude granular	none
Application Method	Fixed- or rotary-wing	Fixed- or rotary-wing
Cab Type	Open Cab or Closed Cab with Open Window	Open Cab; Closed Cab with Open Window

[a] Subsets of Applicator data in the Pesticide Handlers Exposure Database (PHED). Parameter descriptions are from screens displayed in the PHED program.
[b] Data quality grades are defined in the text and in Versar (1992).

Figure 3-1. Summary of results from the Pesticide Handlers Exposure Database (PHED) subset [a]

SUMMARY STATISTICS FOR CALCULATED DERMAL EXPOSURES
SCENARIO: Long pants, long sleeves, gloves

PATCH LOCATION	MICROGRAMS PER LB AI SPRAYED Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	4.212	118.2574	1.2438	10
NECK.FRONT	.414	143.6715	.1169	10
NECK.BACK	.3124	139.1485	.0741	10
UPPER ARMS	8.5554	109.6232	5.7532	10
CHEST	6.3065	158.1987	2.1395	17
BACK	8.7497	141.5614	3.131	17
FOREARMS	2.7901	131.7516	1.1744	17
THIGHS	9.55	157.4126	3.4718	13
LOWER LEGS	7.4494	138.0769	3.3312	10

Subset Name:
S17DERMAL.APPL

[a] Subset criteria included actual and estimated head patches. Of the 10 head observations, 7 were actual and 3 were estimated from nearby patches (Versar, 1992).

Table 3-2. PHED data from dermal, hand, and inhalation subsets [a]

Exposure Category	Exposure (µg/lb AI handled) [a]	Replicates in subset [b]	Short-Term Multiplier [c]	Long-Term Multiplier [c]
Dermal (non-hand) [d]	52.21	10	6	2
Hand (with gloves)	9.63	9	6	2
Inhalation	0.573	14	5	2

[a] Results from subsets of Mixer/Loader data in the Pesticide Handlers Exposure Database (PHED).
[b] Median number of replicates was used for Dermal (non-hand).
[c] Multipliers are explained in the Exposure Assessment section and in Powell (2002).
[d] Dermal total includes addition of default feet value of 0.52 x (value for lower legs); ratio of feet/lower leg surface area (U.S. EPA, 1997).

Table 3-3. Values Used in Short-Term and Long-Term Exposure Calculations [a]

	Short-Term		Long-Term	
Total Dermal	6(52.21) + 6(9.63) =	371 µg/lb AI handled	2(52.21) + 2(45.64) =	124 µg/lb AI handled
Inhalation [b]	5(0.057) =	0.286 µg/lb AI handled	2(0.057) =	0.115 µg/lb AI handled

[a] Values from Table 3-2.
[b] Inhalation data multiplied by 0.1 for use of respirator (NIOSH, 1987).

Appendix 4: Flagger, Liquids

Table 4-1. Description of PHED subsets [a]

Parameter	Specifications used to generate subsets	Actual characteristics of resulting subsets
Data Quality Grades [b]	A,B	A,B
Liquid Type or Solid Type	Not specified	Emulsifiable concentrate or dry flowable.
Application Method	Fixed- or rotary-wing	All rotary-wing

[a] Subsets of Flagger data in the Pesticide Handlers Exposure Database (PHED). Parameter descriptions are from screens displayed in the PHED program.
[b] Data quality grades are defined in the text and in Versar (1992).

Figure 4-1. Summary of results from the Pesticide Handlers Exposure Database (PHED) subset [a]

SUMMARY STATISTICS FOR CALCULATED DERMAL EXPOSURES

SCENARIO: Long pants, long sleeves, gloves

PATCH LOCATION	MICROGRAMS PER LB AI SPRAYED Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	11.3028	127.5702	5.6188	18
NECK.FRONT	.9533	134.3334	.5146	18
NECK.BACK	1.4111	215.8529	.4931	18
UPPER ARMS	3.9285	195.1025	.8284	28
CHEST	5.1065	188.8378	1.0384	26
BACK	5.1065	188.8378	1.0384	26
FOREARMS	1.802	179.5283	.3837	28
THIGHS	4.0404	308.6996	.9165	26
LOWER LEGS	2.448	305.6618	.612	28

Subset Name: S7DERMAL.FLAG

[a] Subset criteria included actual and estimated head patches. Of the 18 head observations, all were actual.

Table 4-2. PHED data from dermal, hand, and inhalation subsets [a]

Exposure Category	Exposure (µg/lb AI handled) [a]	Replicates in subset [b]	Short-Term Multiplier [c]	Long-Term Multiplier [c]
Dermal (non-hand) [d]	37.37	26	4	1
Hand (no gloves)	5.97	30	4	1
Inhalation	0.200	28	4	1

[a] Results from subsets of Mixer/Loader data in the Pesticide Handlers Exposure Database (PHED).
[b] Median number of replicates was used for Dermal (non-hand).
[c] Multipliers are explained in the Exposure Assessment section and in Powell (2002).
[d] Dermal total includes addition of default feet value of 0.52 x (value for lower legs); ratio of feet/lower leg surface area (U.S. EPA, 1997).

Table 4-3. Values Used in Short-Term and Long-Term Exposure Calculations [a]

	Short-Term		Long-Term	
Total Dermal [b]	4(37.37) + 4(0.597) =	152 µg/lb AI handled	1(37.37) + 1(0.597) =	38.0 µg/lb AI handled
Inhalation [b]	4(0.020) =	0.080 µg/lb AI handled	1(0.020) =	0.020 µg/lb AI handled

[a] Values from Table 4-2.
[b] Hand data multiplied by 0.1 for gloves (Aprea *et al*., 1994). Inhalation data multiplied by 0.1 for use of respirator (NIOSH, 1987).

Appendix 5: Airblast Applicator, Open Cab

Table 5-1. Description of PHED subsets [a]

Parameter	Specifications used to generate subsets	Actual characteristics of resulting subsets
Data Quality Grades [b]	A,B	A,B
Liquid Type or Solid Type	Not specified	Emulsifiable concentrate, dry flowable or wettable powder
Application Method	Airblast	Airblast
Cab Type	Open Cab or Closed Cab with Open Window	Open Cab or Closed Cab with Open Window

[a] Subsets of Applicator data in the Pesticide Handlers Exposure Database (PHED). Parameter descriptions are from screens displayed in the PHED program.
[b] Data quality grades are defined in the text and in Versar (1992).

Figure 5-1. Summary of results from the Pesticide Handlers Exposure Database (PHED) subset [a]

SUMMARY STATISTICS FOR CALCULATED DERMAL EXPOSURES
SCENARIO: Long pants, long sleeves, gloves

PATCH LOCATION	MICROGRAMS PER LB AI SPRAYED Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	778.5762	155.5207	176.2608	42
NECK.FRONT	37.1325	147.948	12.193	38
NECK.BACK	27.8342	159.3144	8.7825	42
UPPER ARMS	42.3987	265.4846	6.4049	40
CHEST	21.8289	177.8784	5.4396	49
BACK	14.7289	174.1332	4.204	49
FOREARMS	7.4511	148.7525	2.0066	38
THIGHS	56.8344	189.968	16.9924	32
LOWER LEGS	17.2699	129.16	7.0944	32

Subset Name:
S9DERMAL.APPL

[a] Subset criteria included actual and estimated head patches. Of the 42 head observations, 41 were actual and 1 was estimated from nearby patches (Versar, 1992).

Table 5-2. PHED data from dermal, hand, and inhalation subsets [a]

Exposure Category	Exposure (µg/lb AI handled) [a]	Replicates in subset [b]	Short-Term Multiplier [c]	Long-Term Multiplier [c]
Dermal (non-hand) [d]	1013	40	4	1
Hand (with gloves)	8.53	18	5	1
Inhalation	5.41	47	4	1

[a] Results from subsets of Mixer/Loader data in the Pesticide Handlers Exposure Database (PHED).
[b] Median number of replicates was used for Dermal (non-hand).
[c] Multipliers are explained in the Exposure Assessment section and in Powell (2002).
[d] Dermal total includes addition of default feet value of 0.52 x (value for lower legs); ratio of feet/lower leg surface area (U.S. EPA, 1997).

Table 5-3. Values Used in Short-Term and Long-Term Exposure Calculations [a]

	Short-Term		Long-Term	
Total Dermal	4(1013) + 5(8.53) =	4,090 µg/lb AI handled	1(1013) + 1(8.53) =	1,020 µg/lb AI handled
Inhalation [b]	4(0.541) =	2.16 µg/lb AI handled	1(0.541) =	0.541 µg/lb AI handled

[a] Values from Table 5-2.
[b] Inhalation data multiplied by 0.1 for use of respirator (NIOSH, 1987).

Appendix 6: Groundboom Applicator, Open Cab

Table 6-1. Description of PHED subsets [a]

Parameter	Specifications used to generate subsets	Actual characteristics of resulting subsets
Data Quality Grades [b]	A,B	A,B
Liquid Type or Solid Type	Not specified	Emulsifiable concentrate or wettable powder
Application Method	Groundboom, Truck or Tractor	Groundboom, Tractor (all)
Cab Type	Open Cab or Closed Cab with Open Window	Open Cab or Closed Cab with Open Window

[a] Subsets of Applicator data in the Pesticide Handlers Exposure Database (PHED). Parameter descriptions are from screens displayed in the PHED program.
[b] Data quality grades are defined in the text and in Versar (1992).

Figure 6-1. Summary of results from the Pesticide Handlers Exposure Database (PHED) subset [a]

SUMMARY STATISTICS FOR CALCULATED DERMAL EXPOSURES

SCENARIO: Long pants, long sleeves, no gloves

PATCH LOCATION	MICROGRAMS PER LB AI SPRAYED Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	2.7891	136.1192	1.0464	33
NECK.FRONT	1.5763	167.9503	.3296	23
NECK.BACK	1.0063	173.5765	.2335	29
UPPER ARMS	1.6914	88.749	1.1637	32
CHEST	1.7581	98.5154	1.1329	42
BACK	3.0175	233.2361	1.3959	42
FOREARMS	2.7301	419.1055	.564	32
THIGHS	3.1255	185.5703	1.1806	33
LOWER LEGS	2.1148	172.3425	.7466	35

Subset Name:
S11DERMAL.APPL

[a] Subset criteria included actual and estimated head patches. Of the 33 head observations, all were actual.

Table 6-2. PHED data from dermal, hand, and inhalation subsets [a]

Exposure Category	Exposure (µg/lb AI handled) [a]	Replicates in subset [b]	Short-Term Multiplier [c]	Long-Term Multiplier [c]
Dermal (non-hand) [d]	20.91	33	4	1
Hand (no gloves)	45.64	29	4	1
Inhalation	1.12	22	4	1

[a] Results from subsets of Mixer/Loader data in the Pesticide Handlers Exposure Database (PHED).
[b] Median number of replicates was used for Dermal (non-hand).
[c] Multipliers are explained in the Exposure Assessment section and in Powell (2002).
[d] Dermal total includes addition of default feet value of 0.52 x (value for lower legs); ratio of feet/lower leg surface area (U.S. EPA, 1997).

Table 6-3. Values Used in Short-Term and Long-Term Exposure Calculations [a]

	Short-Term		Long-Term	
Total Dermal	4(20.91) + 4(4.56) =	102 µg/lb AI handled	1(20.91) + 1(4.56) =	25.5 µg/lb AI handled
Inhalation	4(0.112) =	0.448 µg/lb AI handled	1(0.112) =	0.112 µg/lb AI handled

[a] Values from Table 6-2.
[b] Hand data multiplied by 0.1 for gloves (Aprea *et al*., 1994). Inhalation data multiplied by 0.1 for use of respirator (NIOSH, 1987).

Appendix 7: Backpack M/L/A, liquid (open pour)

Table 7-1. Description of PHED subsets [a]

Parameter	Specifications used to generate subsets	Actual characteristics of resulting subsets
Data Quality Grades [b]	A,B,C	A,B,C
Liquid Type	Not specified	Solution, Microencapsulated
Application Method	Backpack	Backpack
Mixing Procedure	Open	Open

[a] Subsets of Mixer/Loader/Applicator data in the Pesticide Handlers Exposure Database (PHED). Parameter descriptions are from screens displayed in the PHED program.
[b] Data quality grades are defined in the text and in Versar (1992).

Figure 7-1. Summary of results from the Pesticide Handlers Exposure Database (PHED) subset [a]

SUMMARY STATISTICS FOR CALCULATED DERMAL EXPOSURES
SCENARIO: Long pants, long sleeves, gloves

PATCH LOCATION	MICROGRAMS PER AVERAGE LB AI Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	345.2564	194.899	91.4483	11
NECK.FRONT	178.6391	155.1078	38.2719	11
NECK.BACK	1163.209	108.1731	611.9794	11
UPPER ARMS	10116.4827	239.4633	257.2654	11
CHEST	275.4477	170.903	65.7564	11
BACK	8918.1809	167.9854	1044.0635	11
FOREARMS	153.593	184.2219	30.0425	11
THIGHS	597.2782	282.8189	49.147	9
LOWER LEGS	425.8878	230.6324	64.6874	9

Subset Name:
S20DERMAL.MLAP

[a] Subset criteria included actual and estimated head patches. Of the 11 head observations, all were actual.

Table 7-2. PHED data from dermal, hand, and inhalation subsets [a]

Exposure Category	Exposure (µg/lb AI handled) [a]	Replicates in subset [b]	Short-Term Multiplier [c]	Long-Term Multiplier [c]
Dermal (non-hand) [d]	22,200	11	6	2
Hand	9.68	11	6	2
Inhalation	17.5	11	6	2

[a] Results from subsets of Mixer/Loader data in the Pesticide Handlers Exposure Database (PHED).
[b] Median number of replicates was used for Dermal (non-hand).
[c] Multipliers are explained in the Exposure Assessment section and in Powell (2002).
[d] Dermal total includes addition of default feet value of 0.52 x (value for lower legs); ratio of feet/lower leg surface area (U.S. EPA, 1997).

Table 7-3. Values Used in Short-Term and Long-Term Exposure Calculations [a]

	Short-Term		Long-Term	
Total Dermal	6(22,200 + 9.68) =	133,000 µg/lb AI handled	2(22,200 + 9.68) =	44,400 µg/lb AI handled
Inhalation [b]	6(1.75) =	10.5 µg/lb AI handled	2(1.75) =	3.51 µg/lb AI handled

[a] Values from Table 7-2.
[b] Inhalation data multiplied by 0.1 for use of respirator (NIOSH, 1987).

Appendix 8: Low Pressure Handwand M/L/A, Liquid Formulations

Table 8-1. Description of PHED subsets [a]

Parameter	Specifications used to generate subsets	Actual characteristics of resulting subsets
Data Quality Grades [b]	A,B,C	A,B,C
Liquid Type	Emulsifiable concentrate, aqueous suspension, microencapsulated, solution, or undiluted liquid	Solution; Microencapsulated
Application Method	Low Pressure Handwand	Low Pressure Handwand.
Mixing Procedure	Not specified	All open

[a] Subsets of Mixer/Loader/Applicator data in the Pesticide Handlers Exposure Database (PHED). Parameter descriptions are from screens displayed in the PHED program.
[b] Data quality for Airborne estimates were Grades A or B. Data quality grades are defined in the text and in Versar (1992).

Figure 8-1. Summary of results from the Pesticide Handlers Exposure Database (PHED) subset [a]

SUMMARY STATISTICS FOR CALCULATED DERMAL EXPOSURES

SCENARIO: Long pants, long sleeves, gloves

PATCH LOCATION	MICROGRAMS PER AVERAGE LB AI Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	658.5361	136.7049	290.5017	80
NECK.FRONT	137.9226	369.6483	18.9272	80
NECK.BACK	86.3274	429.9868	14.8349	79
UPPER ARMS	111.8313	232.934	32.6211	10
CHEST	235.1875	185.929	48.9756	10
BACK	163.797	202.4421	41.5723	10
FOREARMS	40.9585	267.6492	9.412	10
THIGHS	37.9878	115.1859	27.6737	9
LOWER LEGS	66.9309	164.3135	30.0241	9

Subset Name:
S22DERMAL.MLAP

[a] Subset criteria included actual and estimated head patches. Of the 80 head observations, 10 were actual.

Table 8-2. PHED data from dermal, hand, and inhalation subsets [a]

Exposure Category	Exposure (µg/lb AI handled) [a]	Replicates in subset [b]	Short-Term Multiplier [c]	Long-Term Multiplier [c]
Dermal (non-hand) [d]	1574.3	10	6	2
Hand	10.4	10	6	2
Inhalation	22.8	10	6	2

[a] Results from subsets of Mixer/Loader data in the Pesticide Handlers Exposure Database (PHED).
[b] Median number of replicates was used for Dermal (non-hand).
[c] Multipliers are explained in the Exposure Assessment section and in Powell (2002).
[d] Dermal total includes addition of default feet value of 0.52 x (value for lower legs); ratio of feet/lower leg surface area (U.S. EPA, 1997).

Table 8-3. Values Used in Short-Term and Long-Term Exposure Calculations [a]

	Short-Term	Long-Term
Total Dermal	6(1573.4 + 10.4) = 9,510 µg/lb AI handled	2(1573.4 + 10.4) = 3,170 µg/lb AI handled
Inhalation [b]	6(2.28) = 13.7 µg/lb AI handled	2(2.28) = 4.56 µg/lb AI handled

[a] Values from Table 8-2.
[b] Inhalation data multiplied by 0.1 for use of respirator (NIOSH, 1987).